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APRIL 1950

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON · S·W·I

Established 1869 · Incorporated by Royal Charter 1899

VOL. 164 PART 4

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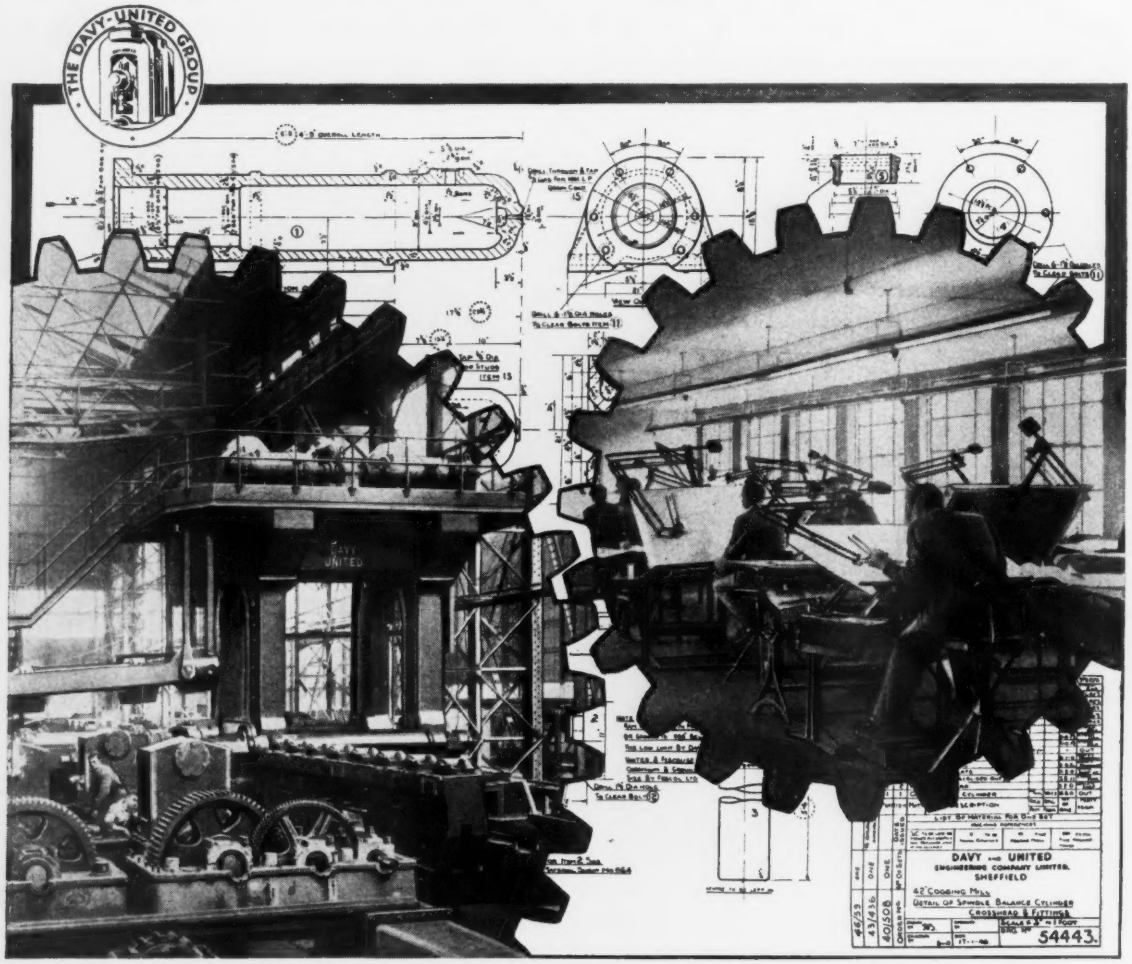
PRODUCTION STORY **DESIGN**

THE Drawing Office of a heavy engineering works is primarily a production department. The rate of progress on the drawing board sets the tempo for all the stages of physical production which follow.

On a recent contract for a cogging mill and a continuous billet mill designed for the same steelworks, we had to make, in addition to drawings for long term delivery items, no fewer than 9,000 individual detail drawings. Every one of these drawings was as much subject to the dictates of time as the parts which were later made from them. Every one had to be fed in properly timed sequence to the shops where the mill was built.

Speed alone, however, is not all. All these drawings must be designed to suit existing production facilities. They must influence sound pattern-making, obey the demands of practical foundry work, be capable of economic machining and lend themselves to simplicity of final erection. Only thus can the work of the Drawing Office be geared really effectively to the work of Production.



DAVY AND UNITED ENGINEERING COMPANY LIMITED SHEFFIELD

SUBSIDIARIES : DAVY AND UNITED ROLL FOUNDRY LIMITED, BILLINGHAM
DUNCAN STEWART & COMPANY LIMITED, GLASGOW

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Part of a Wellman Heat Treatment Installation comprising: Forging Furnace, Tempering Furnace and Forming Machine, for the production of car bumper brackets and the tempering of bumper bars.

The Furnaces are designed to operate within close temperature limits to ensure correct heating of the treated stock and are equipped with conveyor type hearths to facilitate operation at maximum capacity.

We invite you to consult us on any problem in the design and construction of reheating and heat treatment furnaces for ferrous and non-ferrous metals.

THE WELLMAN SMITH OWEN ENGINEERING CORPN. LTD.
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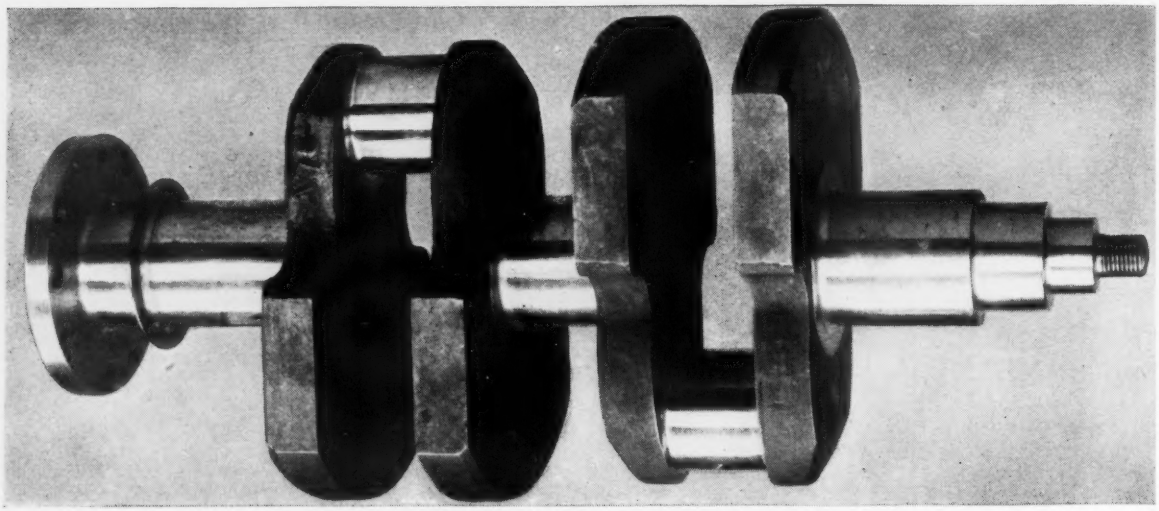
Acicular Iron Castings



Acicular cast iron was chosen for this crankshaft because of its strength and toughness with exceptional resistance to wear, fatigue and shock as well as the advantages in production associated with castings as distinct from forgings. The crankshaft, for use in a two-cylinder 26 h.p. 1000 r.p.m. diesel engine, was cast by W. H. Dorman & Co., Ltd.

Illustration by courtesy of W. H. Dorman & Co., Ltd.

IT was known for some years that cast irons containing nickel and molybdenum sometimes inexplicably showed exceptional strength and toughness with high hardness. Because of the distinctive structure of these irons, they were given the name "acicular." Further study of these exceptional cases led to an additional class of high duty cast iron, for, from the knowledge of how and why they occurred, their controlled production was developed. The procedure, the subject of British Patent 545,102, consists, briefly, of maintaining the molybdenum at 1% and varying the nickel content in accordance with the expected rate of cooling in the mould.

Properties. The mechanical properties vary according to the type of structure produced and the graphite form and content. In the as-cast condition, tensile strengths range from 25-30 tons per sq. in. but by alloy control and subsequent heat-treatment, figures of 40 tons per sq. in. and even higher may be obtained. Similarly by means of heat-treatment, the hardness may be raised above the normal 260-320 Brinell, leaving this iron still readily machinable. Perhaps the most important properties of the acicular irons, however, are their high impact resistance, twice that of pearlitic high duty irons,and their resistance to wear.

Applications. Because of the combination of strength, toughness, high machinable hardness and wear-resistance of acicular cast irons, they are particularly suitable for crankshaft applications. Castings have additional advantages over forgings when applied to crankshafts, because the production to close limits of size and form saves much machining and waste of material. Further uses are to be found in reciprocating machinery where parts are subject to out of balance forces, and even impact. As a particular example, these irons have proved successful for castings subject to repeated shock loading in high-speed automatic textile looms.

Write for a copy of our publication "High Strength Nickel Alloy Cast Iron"

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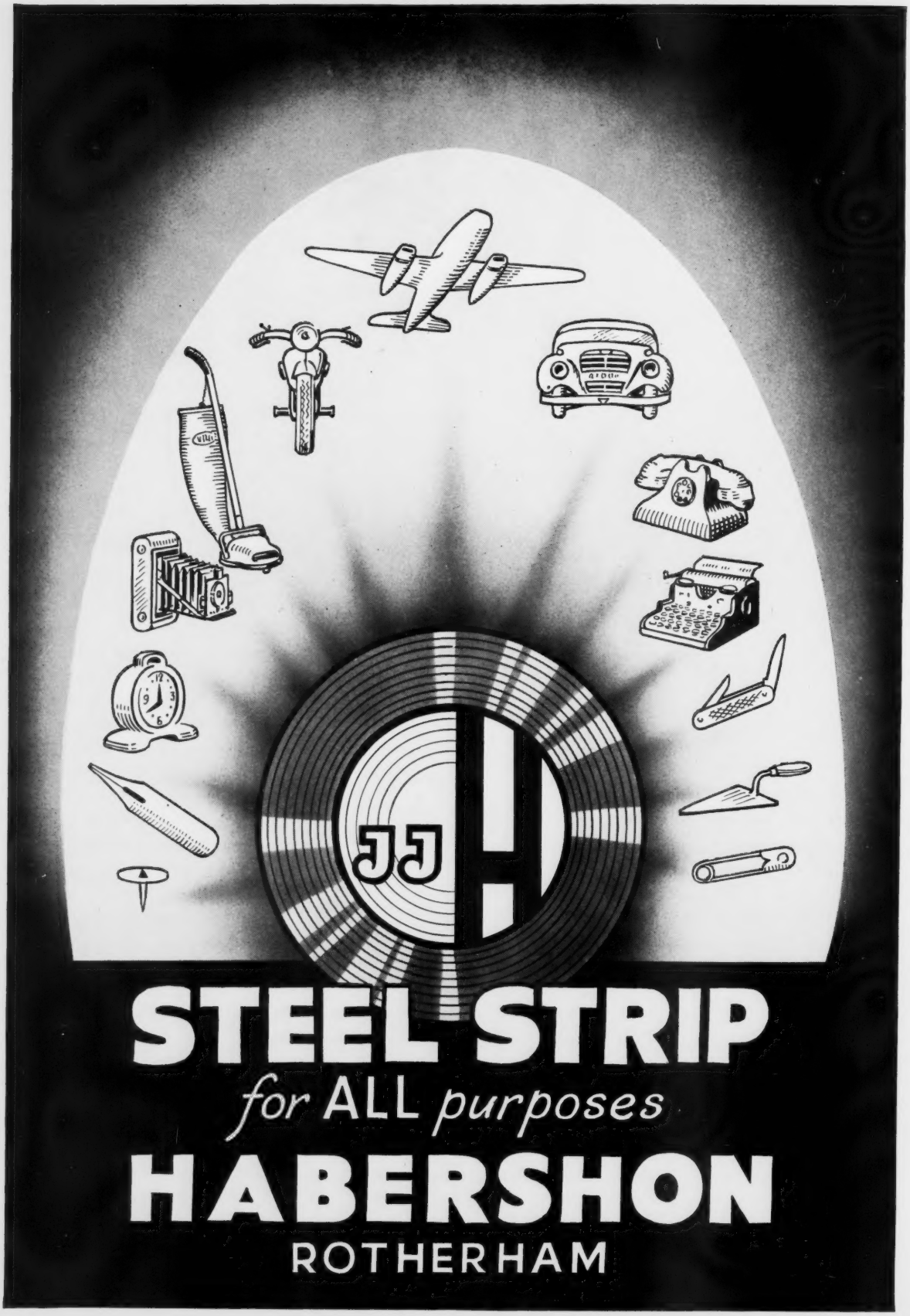
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INCANDESCENT
mechanises yet another
SHEET ROLLING MILL

Photograph shows part of the large, post-war, completely mechanised sheet mill installation at the works of Forges de Leval Aulnoye—France.

This plant includes a bar heating furnace—output twelve tons per hour; two pack heating furnaces, each having an output of six tons per hour and an annealing furnace. All these furnaces are of the well tried Incandescent continuous flow, balanced hearth walking beam type construction and are fired by clean producer gas. The automatic feeder and catcher tables, roll polisher and conveyors were also designed and supplied by :—

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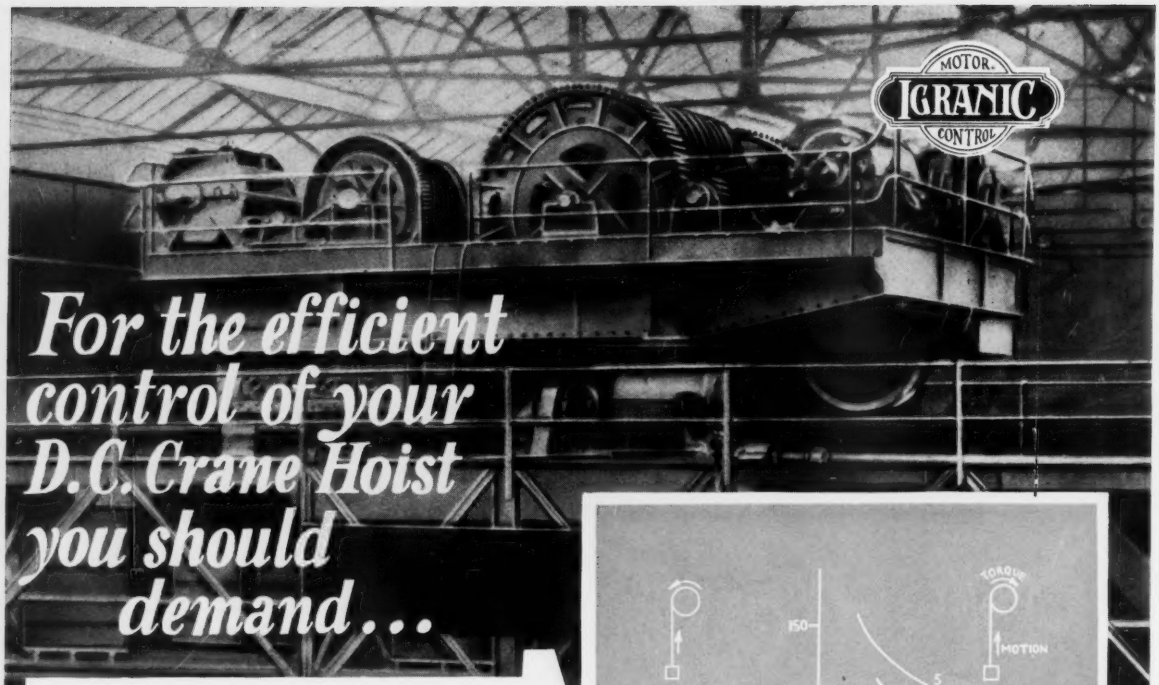

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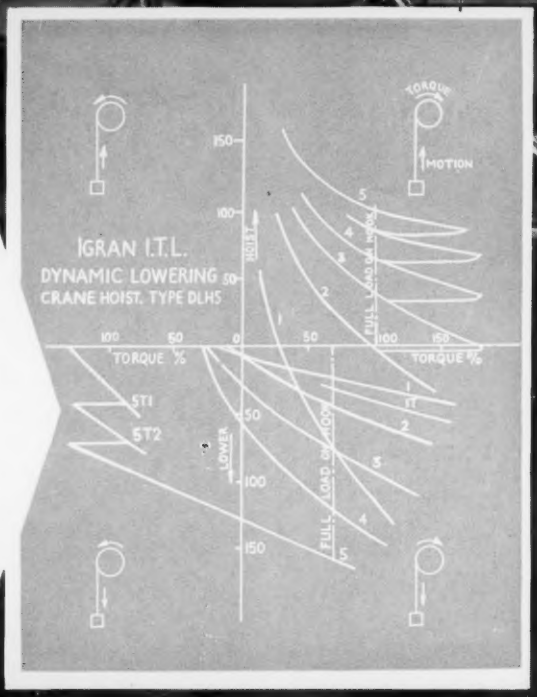

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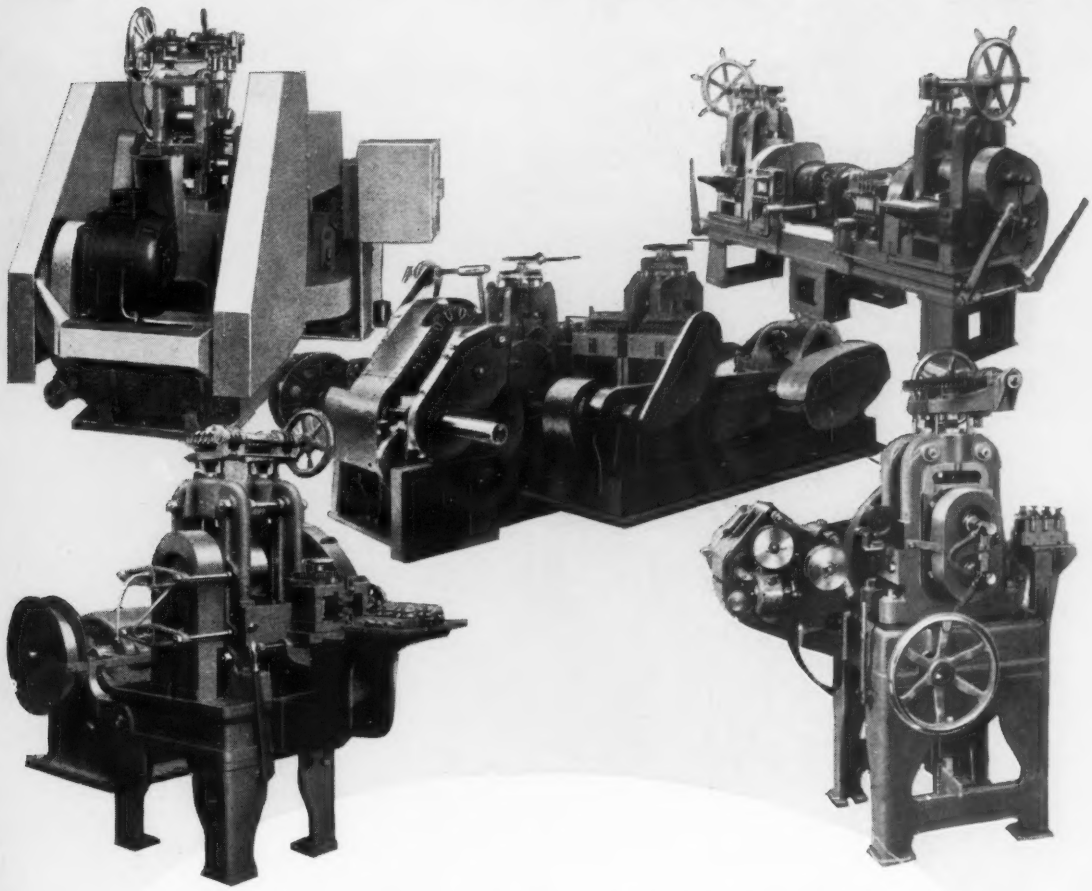

Many years specialised experience of the production of high-grade precision machines has contributed to the development of Robertson Wire Flattening Mills.

The examples illustrated above are from the range of Robertson Mills which are designed for the production of square, rectangular or flat strip from round rod and wire in steel and all non-ferrous metals and alloys.

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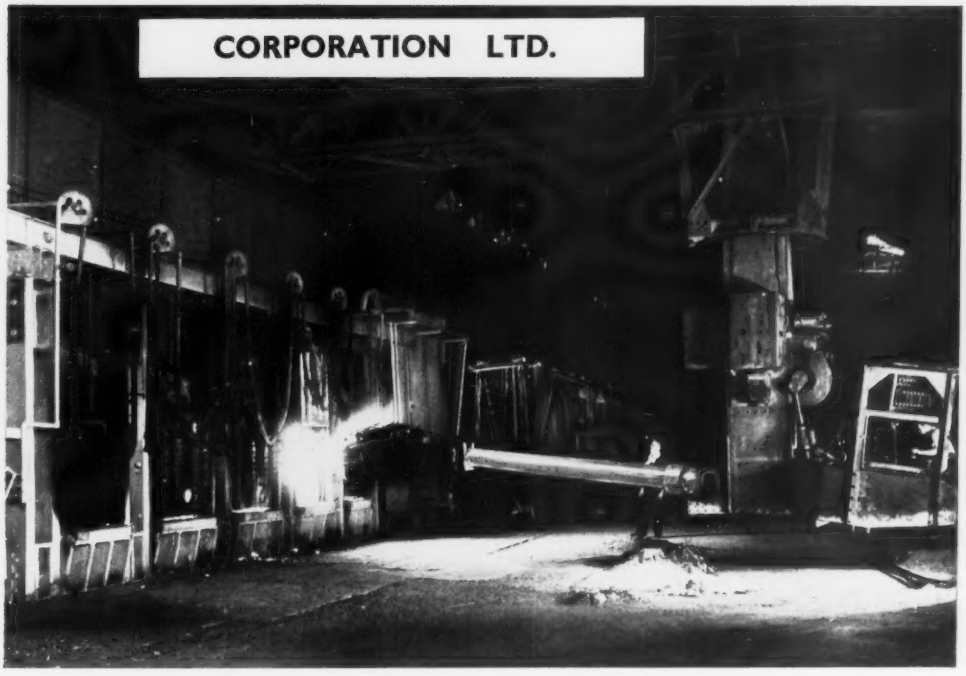

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Data Sheet 5

CHROMIUM–MOLYBDENUM STEELS En. 19 AND 29.

COMPOSITION

Specification.	C.	Mn.	Cr.	Mo.
En. 19	·35/·45%	·5/·8%	·9/1·5%	·20/·40%
En. 29	·15/·35%	·65% max.	2·5/3·5%	·30/·70%

APPLICATIONS

En. 19 Automobile crankshafts, connecting rods, and general high duty engineering components. Suitable for induction hardening.

En. 29 A deeper hardening steel than En. 19 above, suitable for higher strength levels in larger section sizes. Steel within this range of analysis is used for highest quality forgings of large mass, including turbine rotors.

3% Cr-Mo and 3% Cr-Mo-V steels, covered by specifications En. 40 A, B, and C, are widely used in the nitrided condition for aero-engine and high speed diesel engine crankshafts.

HEAT TREATMENT

En. 19 Harden in oil from 850/870° C. Temper at a suitable temperature between 550/720° C.

En. 29 Harden in oil from 890/910° C. Temper at a suitable temperature between 575/750° C.*

* Except for the 100 ton tensile condition up to 2½" ruling section when a 200° C. temper is applied.

MECHANICAL PROPERTIES

En. 19 Especially useful for the 50/60 ton tensile condition, with 40 ft. lb. minimum Izod.

50 tons minimum tensile is given in ruling sections up to 4" dia.

En. 29 Recommended where outstanding notch toughness is required in the 55/65 ton tensile condition for ruling sections up to 6" dia.

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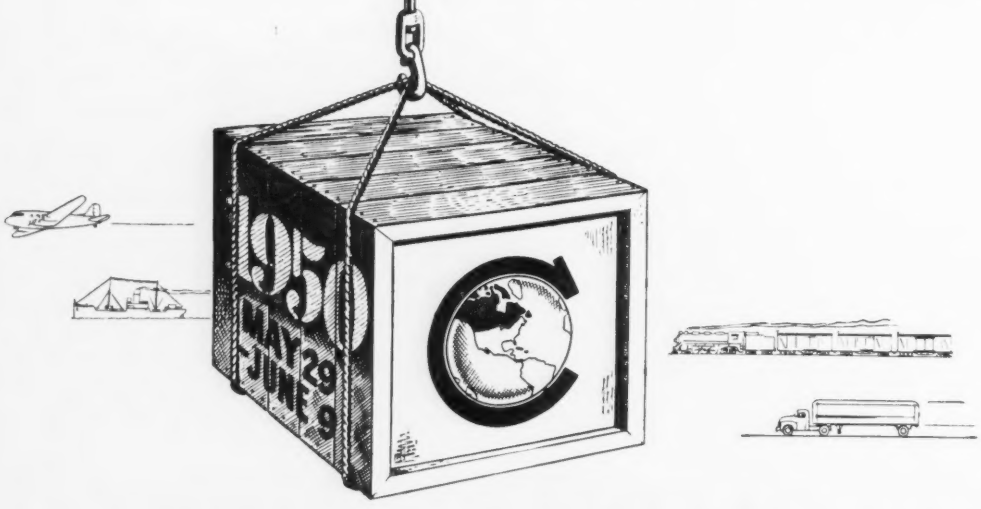

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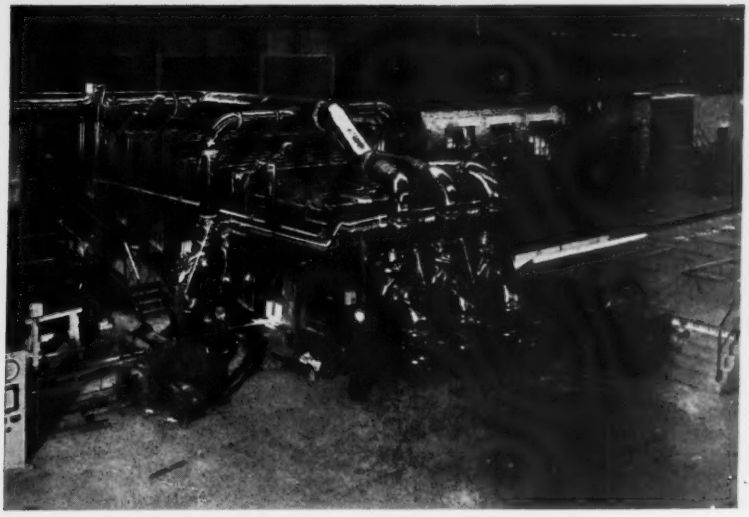

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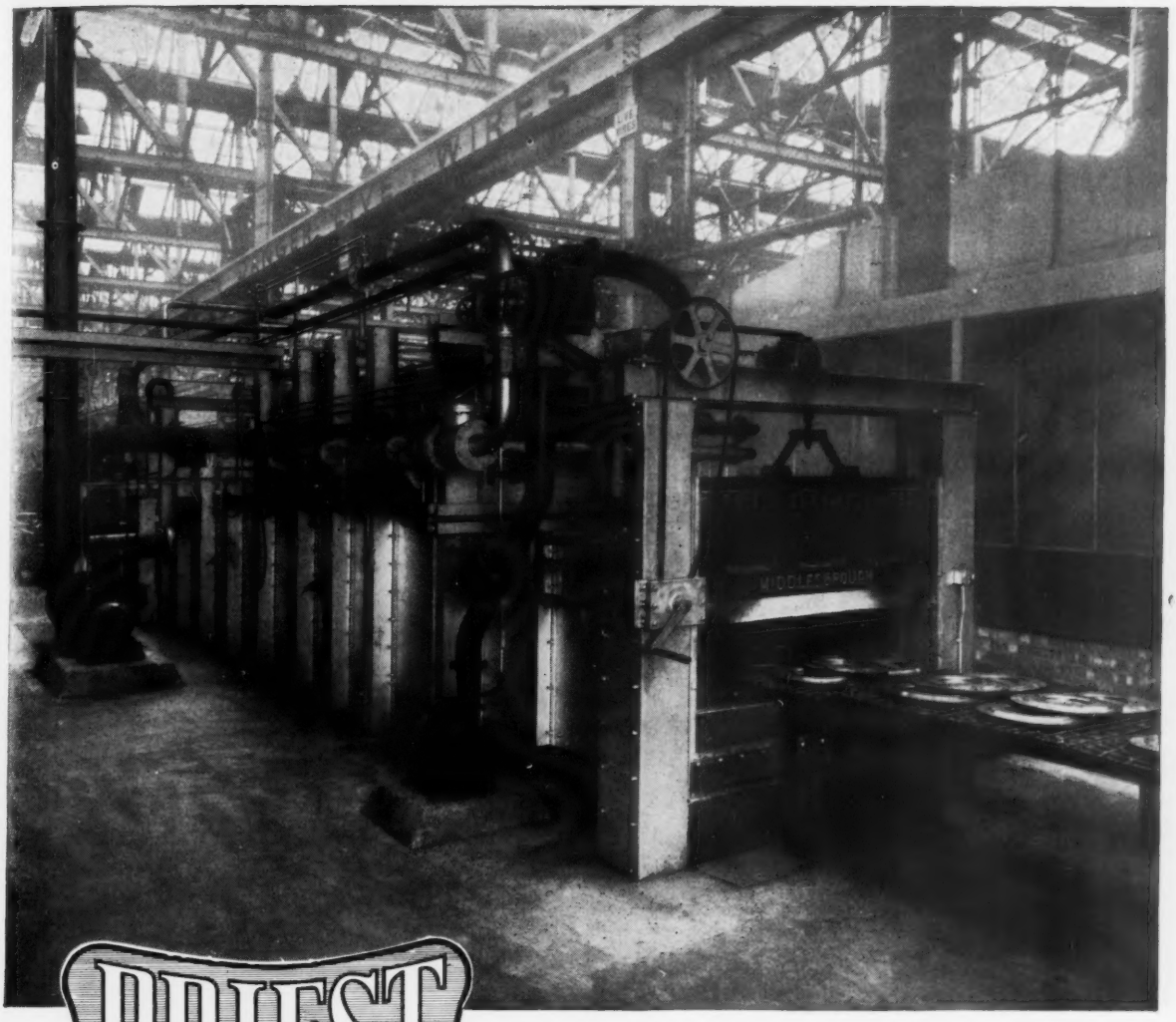

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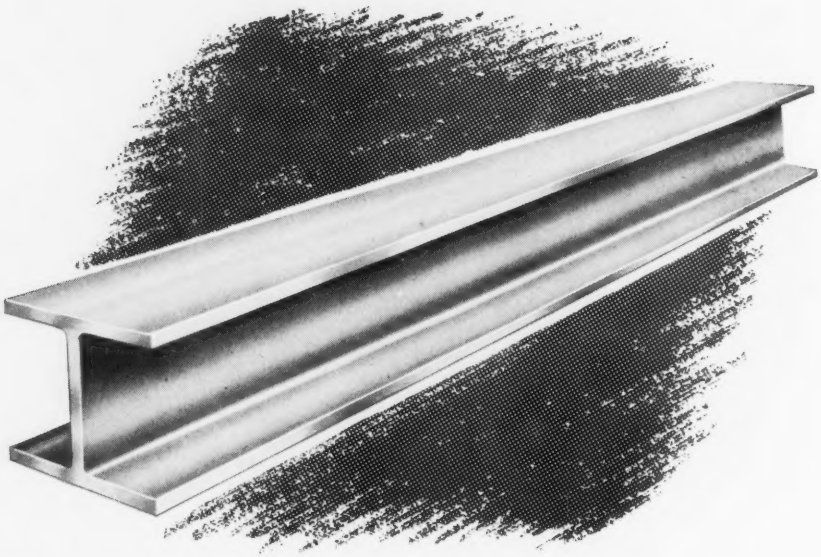

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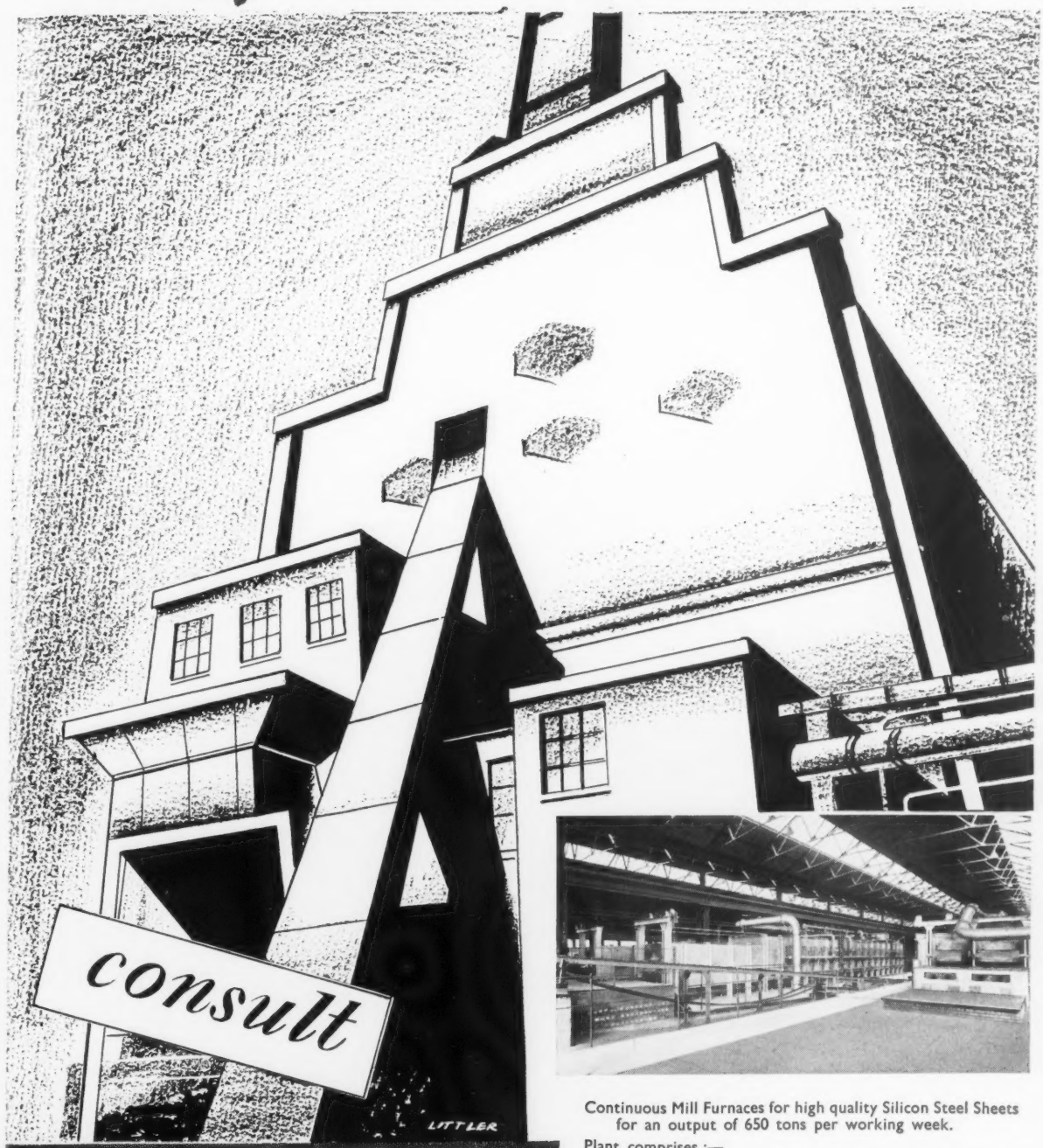

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Plant comprises :—
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Bar Chambers automatically and simultaneously charge and discharge themselves and pack furnaces discharge under electrical push-button control, all furnaces have metal recuperators and special combustion.

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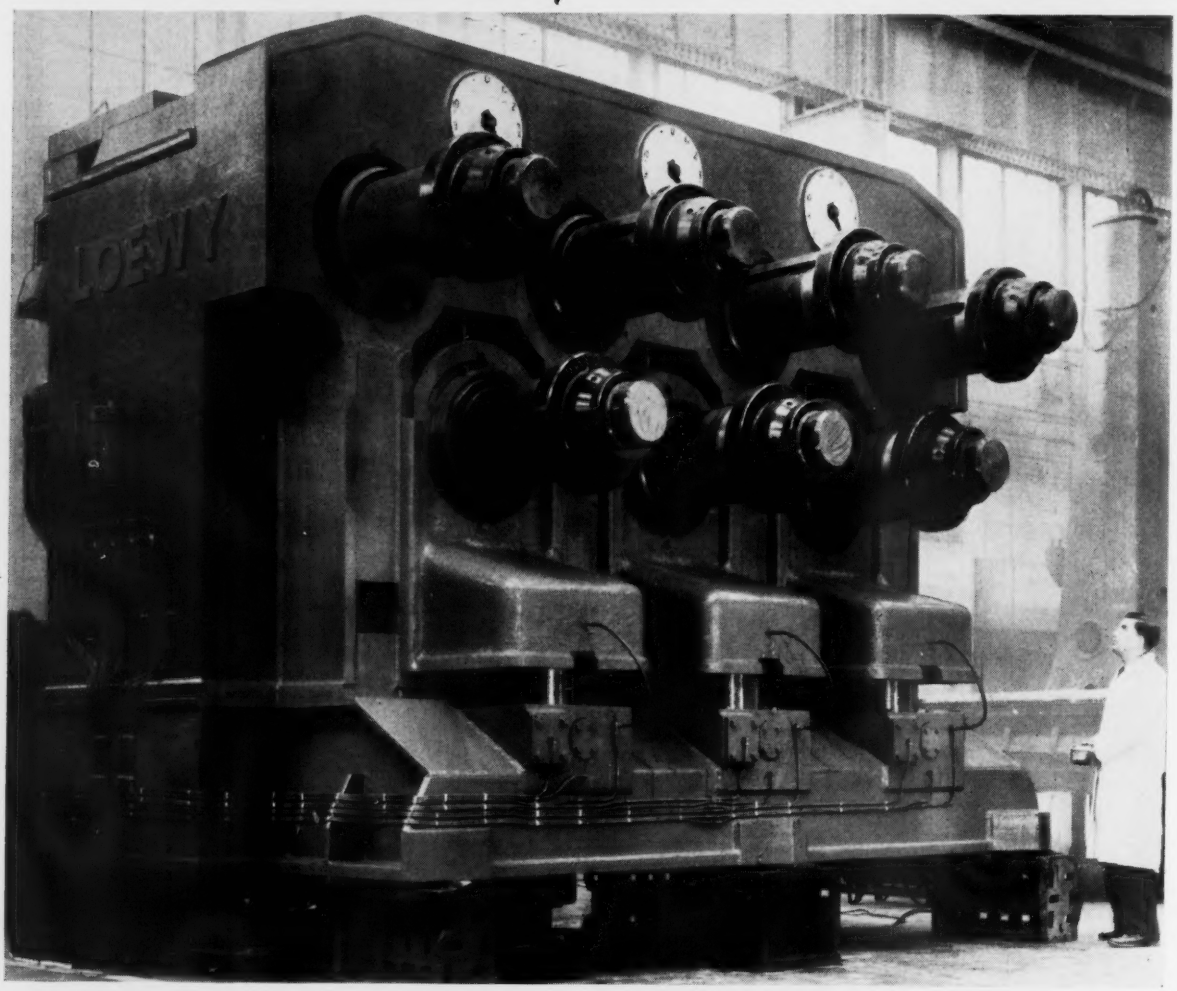

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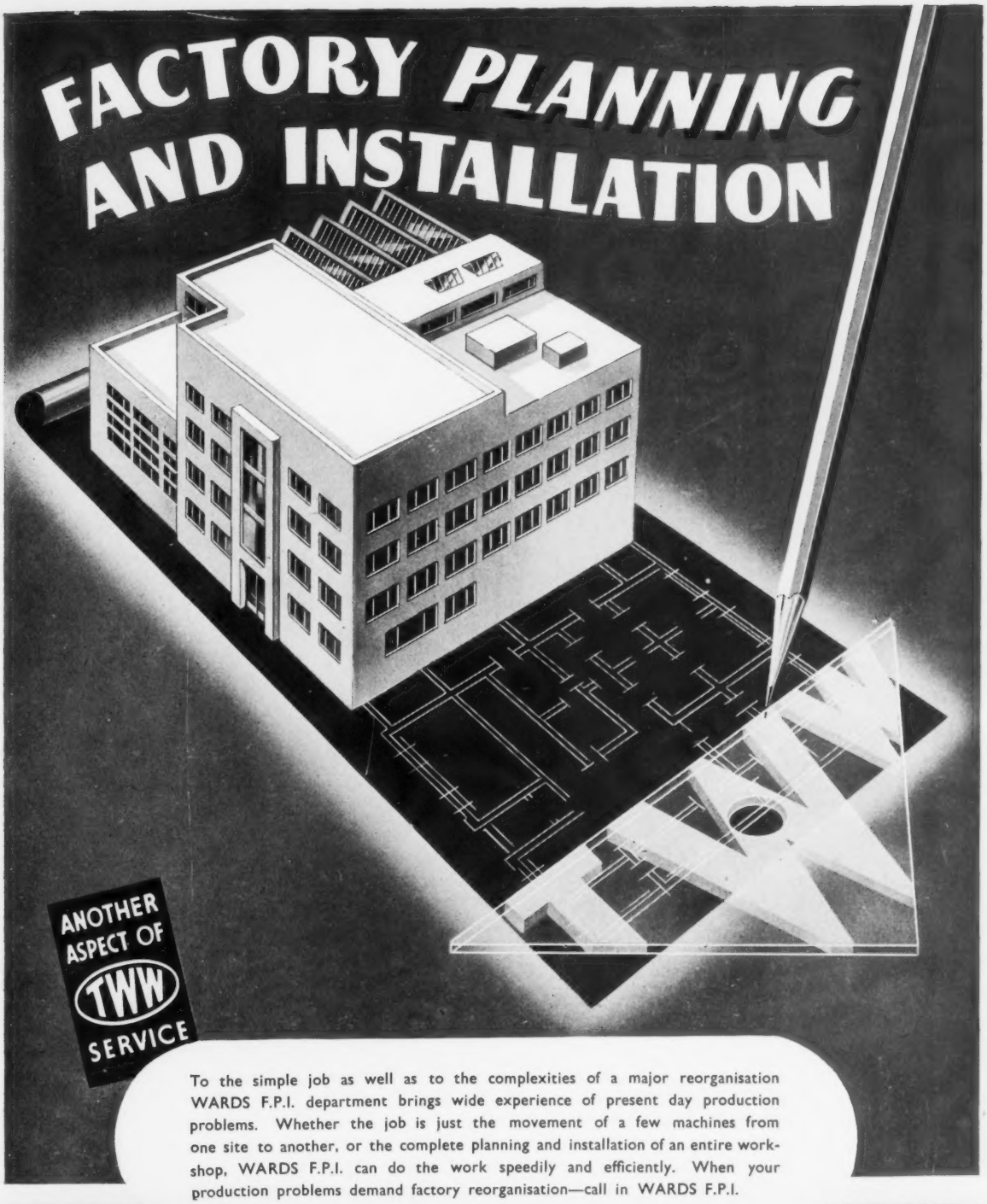

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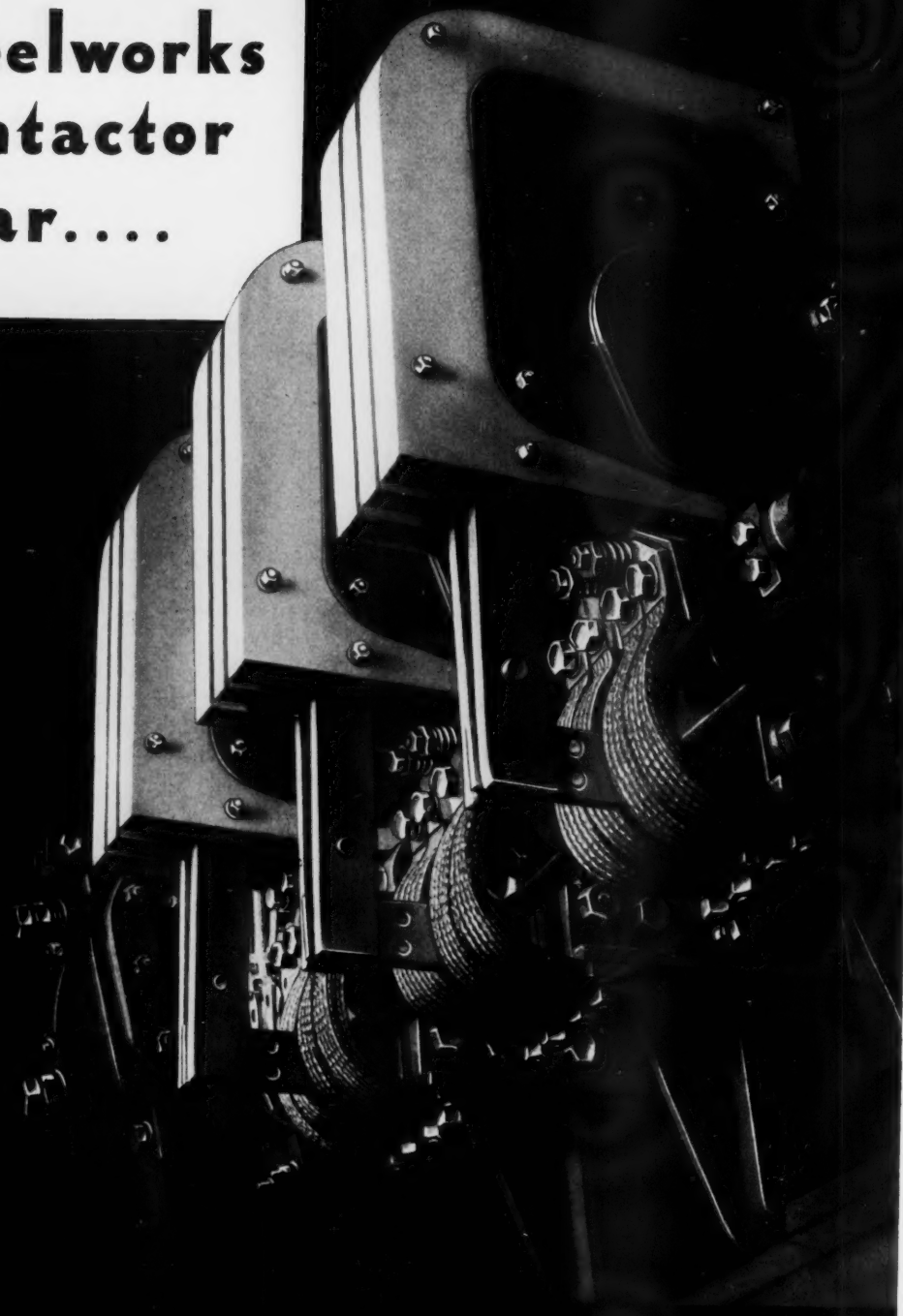

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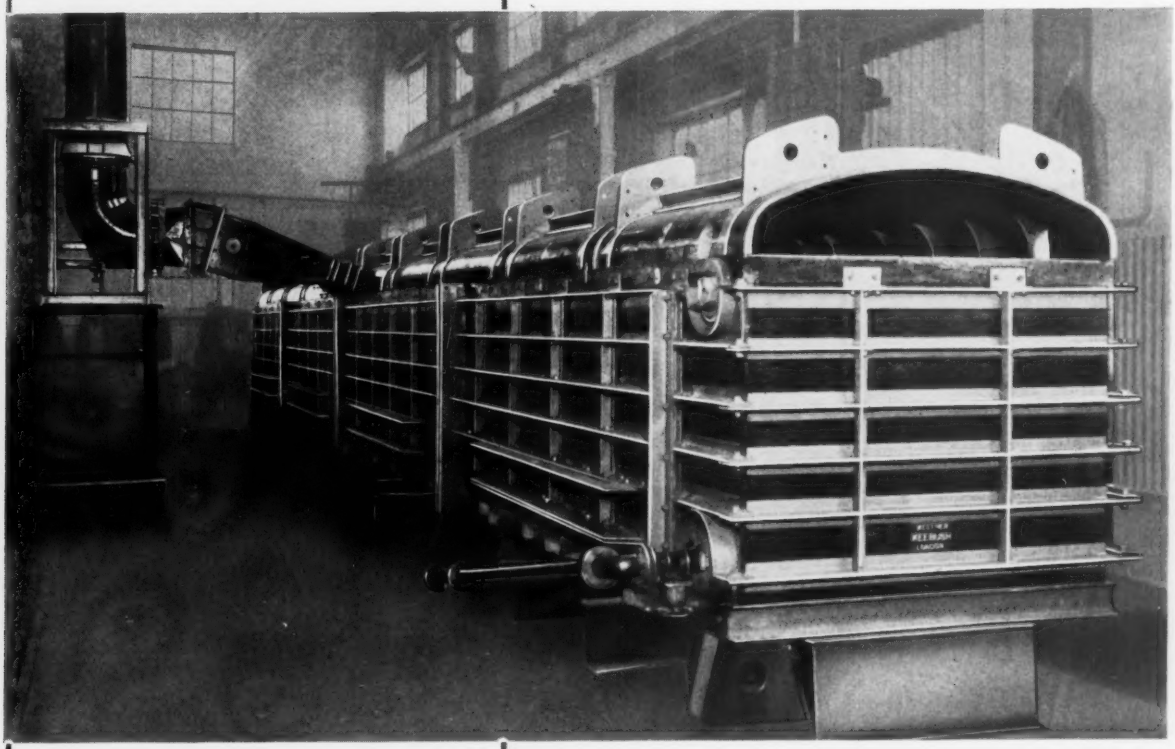
This illustration is of a continuous strip pickling tank, one of a complete line erected for test in our Works. It shows the general construction of the tank, a fume exhaust system with chimney fan, and special hoods. The tank is 60′ 0″ long × 5′ 0″ wide × 5′ 6″ deep. When erected the complete line is 300′ 0″ long. The smaller illustration shows a "dancer roll," being one of the many features embodied in this plant.



STRIP PICKLING TANK

under construction by

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THE CHEMICAL ENGINEERS

The "dancer roll" is made of Keebush throughout.
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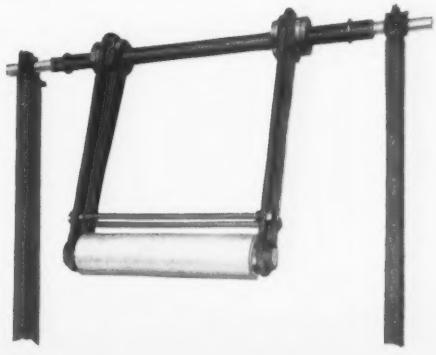

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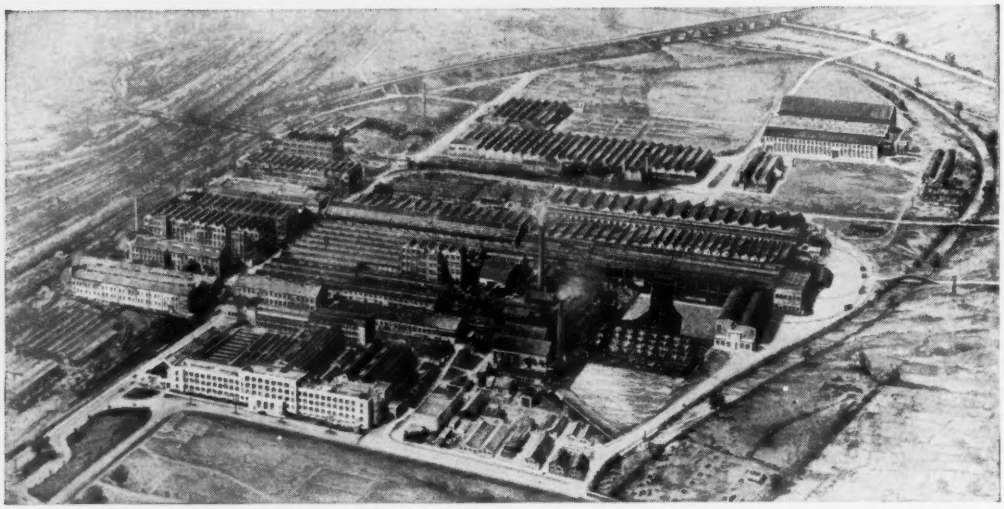

An aerial view of the main works at Rugby.

B
T-H

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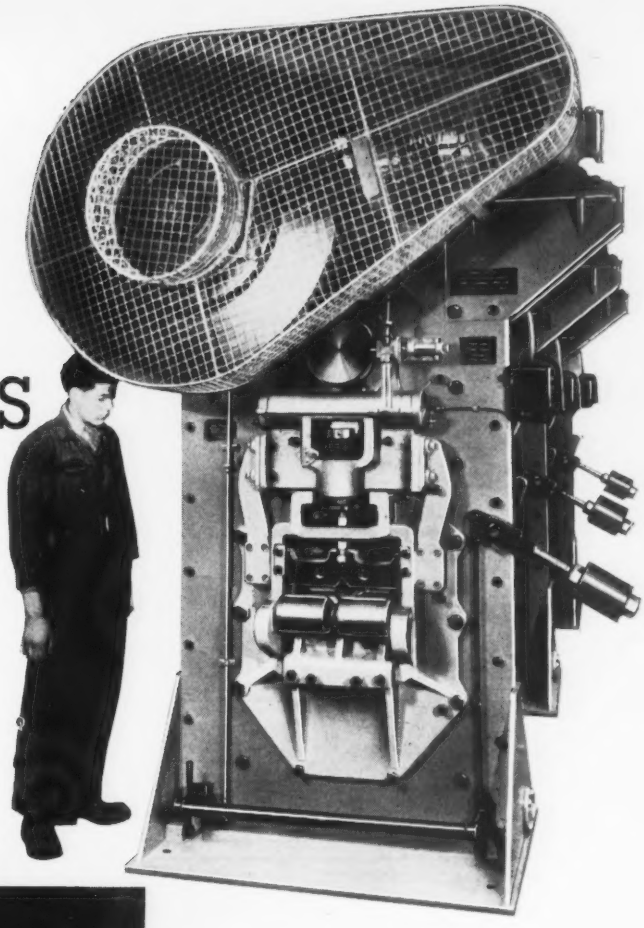

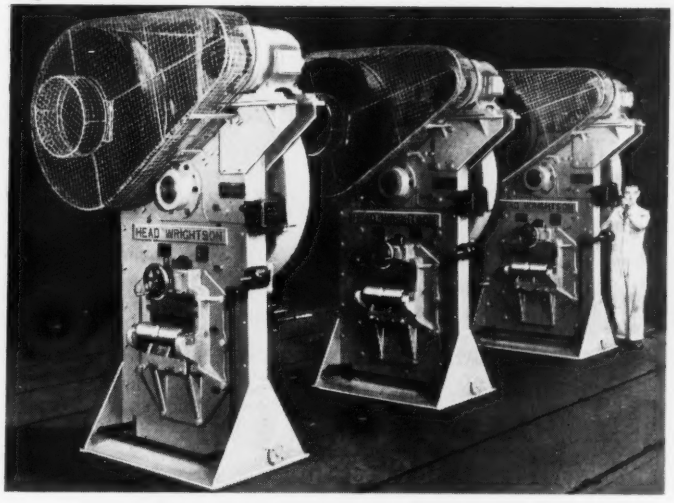

The three Billet Snears illustrated are designed for the cold shearing of mild steel billets up to 2" square in cross section, and form part of an order recently delivered.

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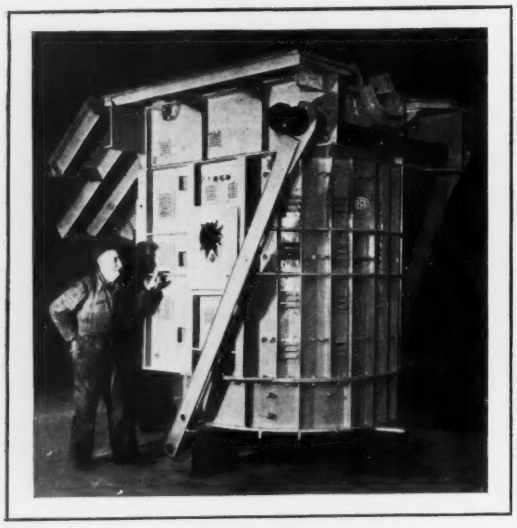
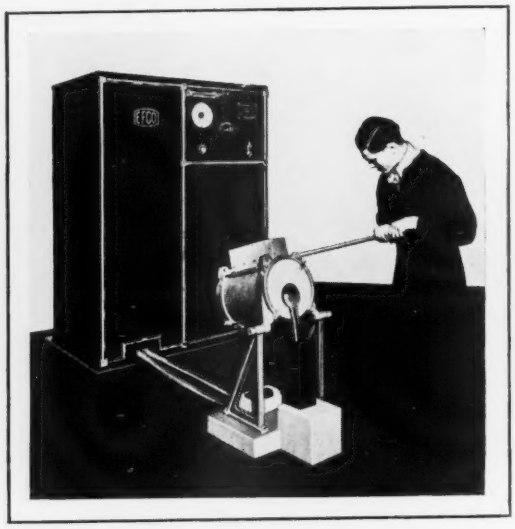


5 ton High Frequency Furnace



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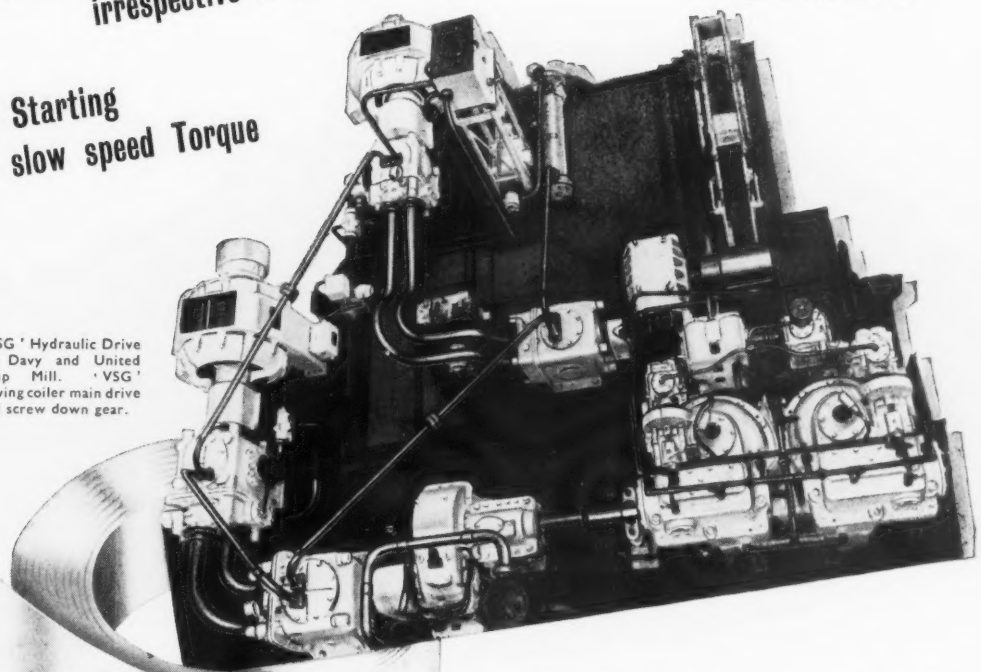

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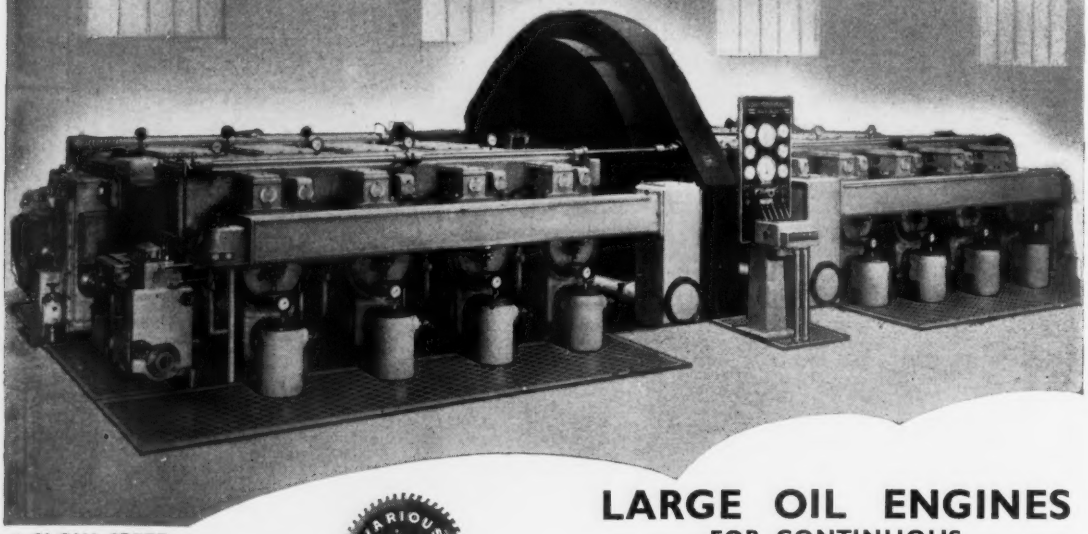

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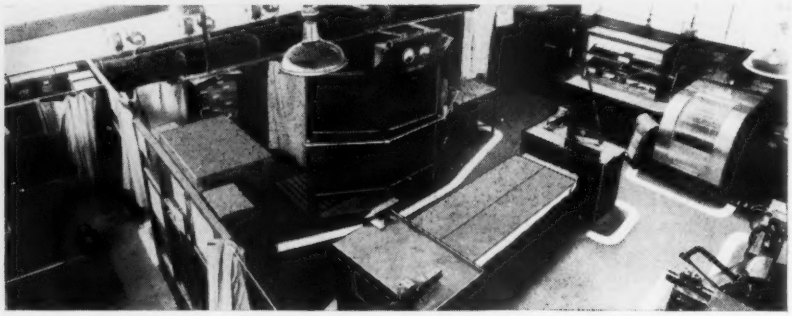

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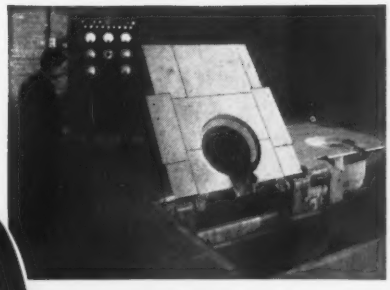
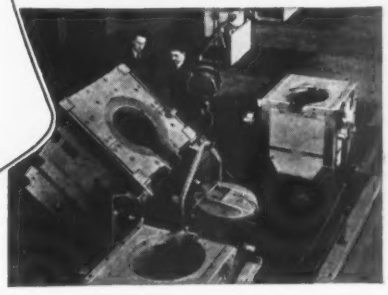


Two 1½ ton furnaces for melting nickel alloys

200 lb. and 100 lb. furnaces for melting ferrous alloys



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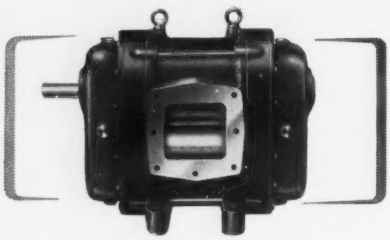

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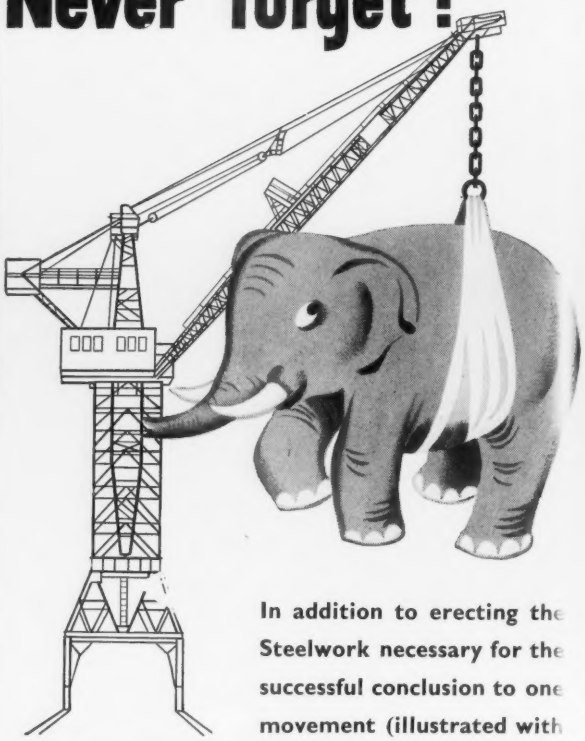

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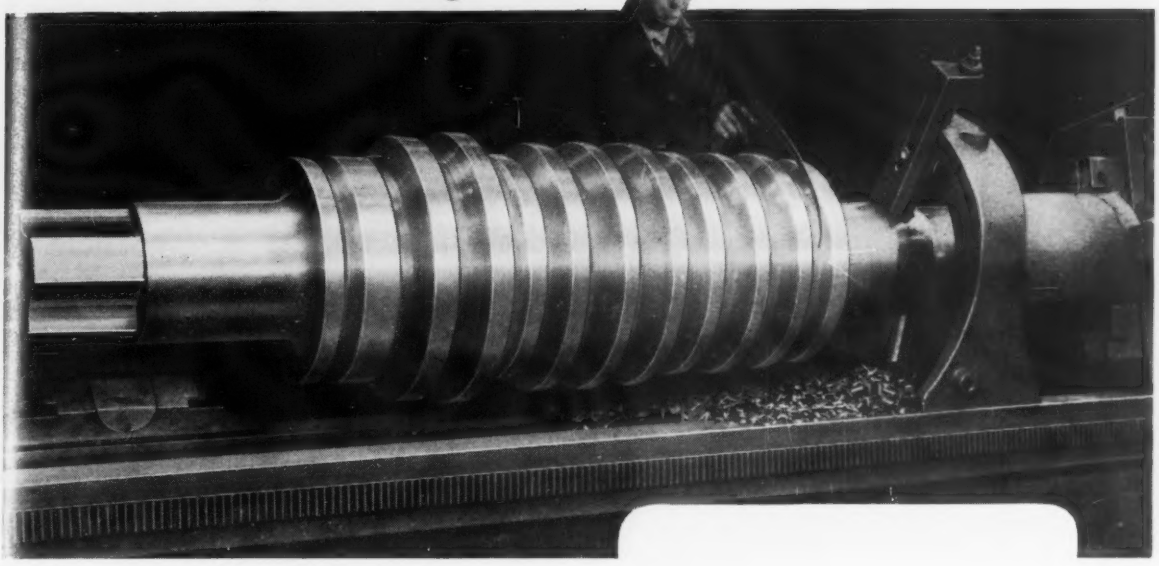

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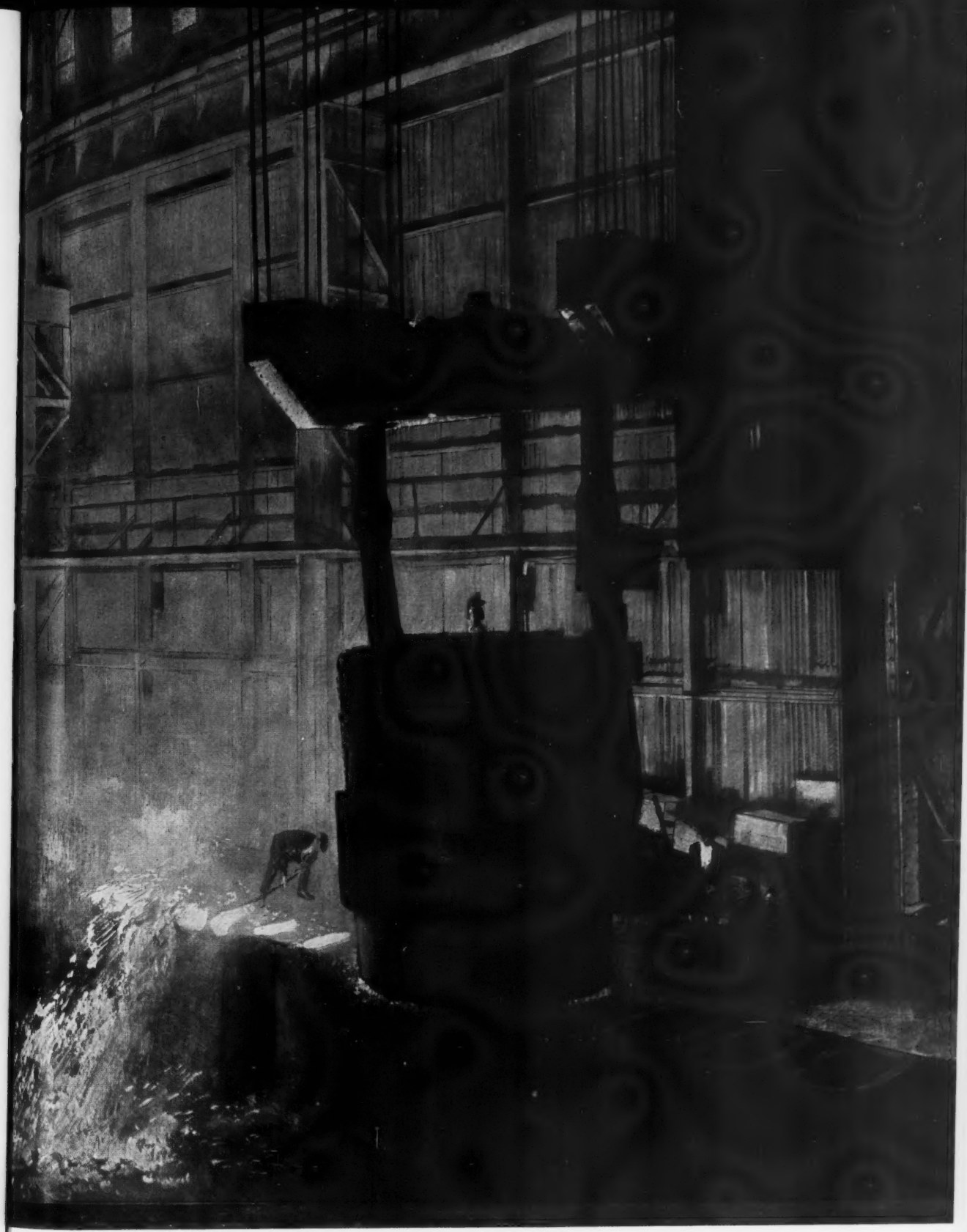

Teeming steel into ingot moulds at the Ebbw Vale works of Richard Thomas & Baldwins, the largest producers of steel sheets and tinplate in the British Isles.

Painting by Anna Zinkeisen

This Present Age . . 3

That unity of purpose can be achieved once the nation is inspired by a sufficiently powerful incentive is one outstanding lesson of the war. We have re-awakened to the fact that we are, first and foremost, citizens of a great nation. Our national ways, whatever their faults and shortcomings, are yet so potent as to demand in their defence all that is best of our faith, courage and even our lives. This spirit must be our urge in the difficult years of reconstruction ; it will be the motive and inspiration of all our endeavours. Granted the desire, goodwill and above all, unity of purpose, the many great and complicated problems can be satisfactorily resolved. No obstacles must be allowed to stand in the way of ensuring such a future and of deserving the just rewards of all our sacrifices. Unity of purpose in peace is the prerequisite of a swift accomplishment of these desirable objects, which of themselves, constitute a dynamic incentive. To keep faith with our comrades who have given their lives for democratic ideals of liberty, all our forces are being mobilised in administration, technology and production, so that by our united efforts we may contribute towards building a better world.

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JOURNAL OF THE IRON AND STEEL INSTITUTE

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WILLIAM B. BAXTER, C.B.E.

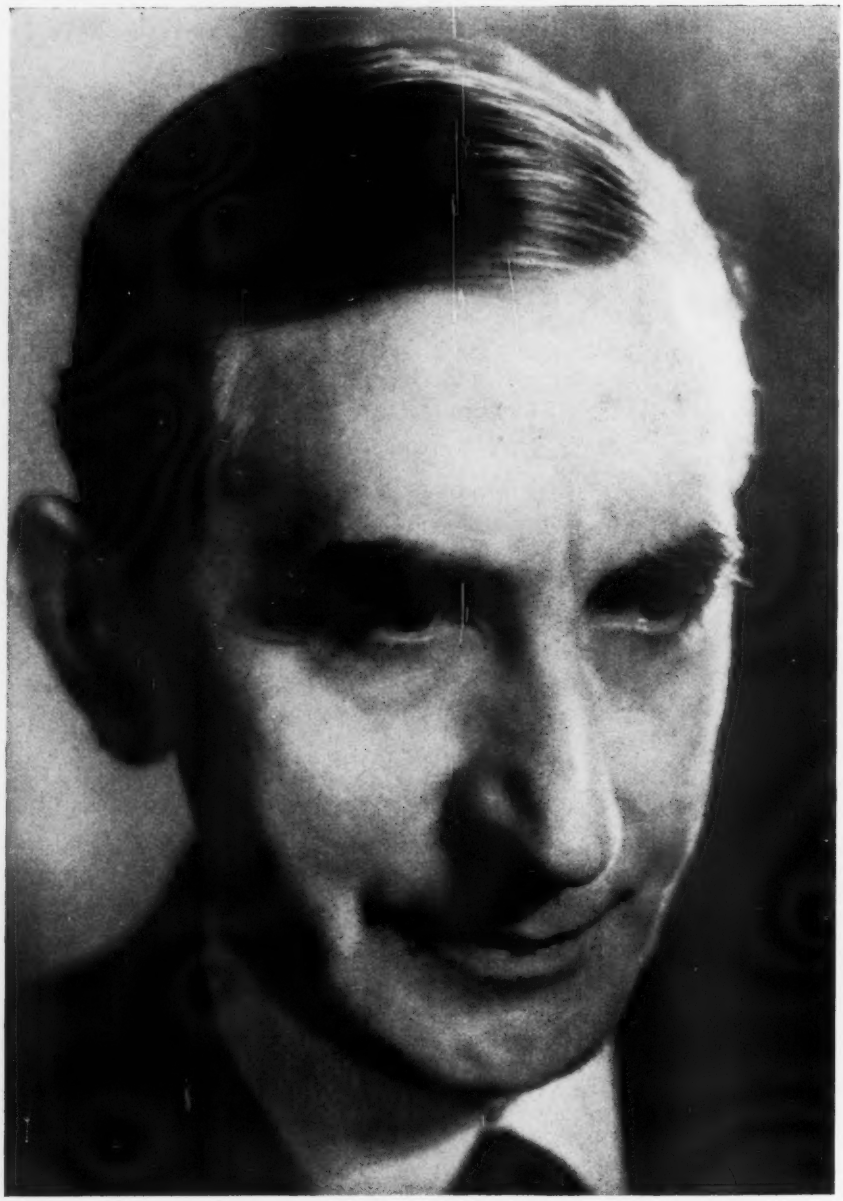
WILLIAM BECK BAXTER, Director of The United Steel Companies Limited, was born at Greenock. He was educated in Glasgow and was trained as an Engineer in that City and in Manchester.

He first became associated with the steel industry in 1914 when he became Electrical Engineer to the Frodingham Iron and Steel Company, now the Appleby-Frodingham Steel Company.

After a period as Assistant to the late Mr. James Henderson, Mr. Baxter became Works Manager of the Appleby-Frodingham Steel Company in 1928 and was appointed to the Board of that Company in 1937. Two years later he was appointed General Manager, a position which he held until 1948, when he resigned to become a Director of the parent Company, The United Steel Companies Limited, and was appointed Technical Consultant to the latter.

Mr. Baxter has always taken a great interest in the technical side of the iron and steel industry. In 1918 he helped to found the Lincolnshire Iron and Steel Institute and became President of that Institute in 1936. During the war years he acted as Chairman of the Lincolnshire Ironmasters Association. He was also associated with the founding of the British Iron and Steel Research Association and was the first Chairman of the Plant Engineering Panel.

He became a Member of The Iron and Steel Institute in 1933, was elected a Member of Council in 1945, and became Vice-President in 1947. He was a member of the Engineering Committee concerned in the formation of the Iron and Steel Engineers Group in 1946.



William B. Baxter, C.B.E.

Vice-President

PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

REPORT OF COUNCIL FOR 1949

THE Council submit this, their Annual Report and Statement of Accounts for the year 1949, to Members for their approval at the Eighty-first Annual General Meeting of The Iron and Steel Institute.

ROLL OF THE INSTITUTE

The membership of the Institute at 31st December, 1949, was 4909, practically the same as a year previously (4903). The upward trend in membership, which has been very marked in recent years (the total is now 92% above the low-water mark of 1941) was checked by the substantial number of resignations which followed the raising of membership subscription rates at the beginning of the year; nevertheless, these resignations were fewer than had been expected. The Council is grateful for the support which Members have continued to give to them in carrying out the policy which they have considered essential to the future well-being of the Institute.

During the year, 331 Ordinary and Associate Members (formerly Associates) were newly elected or reinstated. The deaths of 30 were reported; 218 resigned, 61 were struck off the Roll of Members, and 16 elections lapsed for non-payment of the subscriptions due.

An analysis of the membership at 31st December, 1949, is given in Table I; the membership trend over the years is shown in Fig. 1.

OBITUARY

The Council regret to record the deaths of the following 22 Members which occurred during 1949:

ARMSTRONG, P. A. E. (Westport, Conn., U.S.A.)	7th August
CAMPBELL, *Major* John (London) ...	25th May
CLAPHAM, *Miss* D. P. (Sevenoaks, Kent)	29th June
CLARK, B. F. (Stockport, Cheshire)	25th August
CLERKE, *Major* A. B. H. (Sheffield)	13th May
CUMMINGS, J. H. (Lincoln)... ...	3rd January
CURTIS, A. L. (Chatteris, Cambs.) ...	15th February
DUFFIELD, F. Lindley (Vancouver, B.C., Canada)	22nd July
FISHER, H. T. E. (Thames Ditton, Surrey)	2nd August
HAWKE, O. W. (Worksop, Notts.)	2nd February
JAMISON, R. T. (Stockport, Cheshire)	11th August
LEE, P. W. (Sheffield)	8th June
LUNT, G. T. (Darlaston, Staffs.) ...	4th January
LUX, E. (Roath Park, Cardiff) ...	30th March
METHLEY, B. W. (Rotherham) ...	14th January
MONYPENNY, J. H. G. (Fulwood, Sheffield)	2nd March
MYERS, R. H. (London)	19th February
REICHSFELD, W. M. (London) ...	29th April
ROBERTS, B. (Sheffield)	3rd April
ROWDEN, W. F. (London)	17th March
STIEBER, *Ing.* V. (Prague, Czechoslovakia)	6th November
WENDEL, F. de (Paris, France) ...	12th January

The deaths of the following eight Members occurred during 1948, but were not previously reported:

COOK, R. W. (Bristol, Conn., U.S.A.)	4th December
DAVIS, L. Shaw (London)	11th November
HILL, R. V. (Swansea)	February
PETERSEN, W. J. (Johannesburg, S. Africa)	6th October
ROBINSON, T. W. (Chicago, Ill., U.S.A.)	30th December
WALTON, C. G. (Torquay, Devon) ...	23rd December
WILLIAMS, D. R. P. (Newcastle Emlyn, Carmarthenshire) ...	12th December
DORRINGTON, W. (Henley-in-Arden)	Date unknown

Mr. Lee (1895), Mr. Robinson (1891), and Monsieur de Wendel (1907) were Life Members. They, Mr. Clark (1901), and Mr. Monypenny (1908), had been Members for over forty years, and Major Clerke (1912) only just fell short of this long association with the Institute.

CHANGE IN THE BYE-LAWS

Membership; Subscriptions

At the Annual General Meeting on Wednesday, 27th April, 1949, a resolution to amend Bye-Laws Nos. 3, 21, 35, and 36, making changes in the membership of the Institute and in the rates of subscription, was proposed and carried unanimously. At the Autumn Meeting on Thursday, 10th November, 1949, the President announced that the proposed changes had been authorized by the Privy Council and would take effect as from 1st January, 1950.

The resolution read as follows:

"That the Bye-Laws of the Institute be altered in manner following, that is to say

(1) In Bye-Law No. 3 by adding thereto the words following:—

"It shall also be within the province of the Council to elect Associate Members. The Council shall have power from time to time to make regulations (not inconsistent with anything in these Bye-Laws) for defining the status rights and obligations of associate members, for prescribing the ages and qualifications of candidates for associate membership and providing for the transfer of associate members to ordinary membership of the Institute including the fixing of

Table I—MEMBERSHIP OF THE IRON AND STEEL INSTITUTE AT 31ST DECEMBER, 1949, AND COMPARISON WITH 1948

	Membership at 31st December, 1949												1948		
	Ordinary Membership		Joint Membership with—						Totals		Total Membership		Grand Totals	Total Membership		Grand Totals
			Institute of Metals		Institution of Metallurgists		Both Institute and Institution									
	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas		Home	Overseas	
Patron	1										1	...	1	1	...	1
Members:																
Hon. Vice-Presidents	10	4	1	...	...	...	...	...	1	...	11	4	15	11	4	15
Hon. Members	2	4	1	...	...	...	...	...	1	...	3	4	7	3	4	7
Non-Paying Members	3	1	...	...	...	...	...	...	...	...	3	1	4	3	1	4
Life Members	63	19	2	5	6	...	3	...	11	5	74	24	98	68	25	93
Ordinary Members	1787	249	386	26	348	39	346	746	1080	811	2867	1060	3927	2909	1010	3919
Total (Members)	1866	277	390	31	354	39	349	746	1093	816	2959	1093	4052	2995	1044	4039
Associate Members	258	48	361	28	57	4	98	3	516	35	774	83	857	781	83	864
Total (both classes)	2124	325	751	59	411	43	447	749	1609	851	3733	1176	4909	3776	1127	4903

an entrance fee to be payable on such transfer and for the waiving of the same at the discretion of the Council.

Except where the context otherwise requires, the word "Members" where used in these Bye-Laws shall include members of all classes Provided that an associate member shall not have the right to sign a requisition for a general meeting or to vote at such a meeting or to sign a recommendation for admission to membership or to nominate candidates for election as officers."

(2) By deleting Bye-Law No. 21 and by substituting therefor the following new Bye-Law :—

21. "The entrance fee payable by members on election shall be such sum, if any, as the Council shall from time to time determine.

Until otherwise determined by the Council and sanctioned by a resolution passed at either the Annual General Meeting or the General Meeting held in the Autumn of each year, at which notice of intention to propose the same shall be given :

(*a*) The annual subscription payable by ordinary members shall be £4 4*s*. 0*d*. and by associate members shall be £1 15*s*. 0*d*.

(*b*) Any ordinary member whose subscription is not in arrear may at any time before the 30th June in any year, or if elected after that date in the year, within one month of his election, compound for his subscription for subsequent years on payment according to the following scale :—

Up to 29 years of age	£70
From 30 to 39 years of age	£63
,, 40 to 49 ,, ,, ,, ...	£56
,, 50 to 59 ,, ,, ,, ...	£49
,, 60 years of age and upwards ...	£42

Provided that the adoption of this Bye-Law shall not prejudice the validity of any composition duly effected according to the scale set out in the Bye-Law which is hereby revoked.

Provided also that in the case of any member or associate member who is also a member of the Institute of Metals or of the Institution of Metallurgists or of any other Institute or Society (whether in or out of the United Kingdom) which the Council shall from time to time declare to be a Kindred Society for the purpose of this Bye-Law, the Council shall have power to accept from such member or associate member such reduced subscription under such conditions as it shall from time to time think fit."

(3) By deleting from Bye-Law No. 35 the words "ordinary or honorary" wherever these words occur and also the words "whether ordinary or honorary."

(4) By deleting from Bye-Law No. 36 the words "honorary members and honorary vice-presidents" and the words "honorary members or honorary vice-presidents."

In accordance with the new Bye-Law No. 3, the Council has prepared regulations to govern the class of Associate Members, with effect from 1st January, 1950. These were published on page 92 of the *Journal* for January, 1950 (vol. 164).

Under the terms of the new Bye-Law No. 21, the Council have declared that, in addition to the Institute of Metals and the Institution of Metallurgists, the Affiliated Local Societies, and a number of Societies overseas shall be "Kindred Societies"—*see* "Relations with other Societies."

The increased rates of subscription became effective on 1st January, 1949, by voluntary agreement of Members, pending completion of the formalities involved in changing the Bye-Laws.

CHANGES ON THE COUNCIL

President-Elect

At the Autumn General Meeting it was announced that the Council had unanimously decided to nominate Mr. J. R. Menzies-Wilson, O.B.E., to become President at the Annual General Meeting in 1950.

Other Changes

During 1949 Captain C. A. Ablett, O.B.E., and Mr. Gunnar Schjelderup were elected Honorary Vice-Presidents, in recognition of their services to the Institute. Captain Ablett is the donor of the Ablett Prize, and Mr. Schjelderup, as Chairman of the Main Reception Committee in Oslo, took a leading part in arranging the Special Summer Meeting in Norway.

The following agreed to serve as Honorary Members of Council during their presidencies of the Societies named, in succession to their predecessors: Sir Arthur Smout (Institute of Metals, continuing presidency), Mr. E. T. Judge (Cleveland Institution of Engineers, following Mr. F. Shepherd), Mr. R. C. Powell (Ebbw Vale Metallurgical Society, following Mr. H. F. Padbury), Mr. J. Wilkinson (Leeds Metallurgical Association, following Mr. W. R. Berry), Mr. H. M. Henderson (Lincolnshire Iron and Steel Institute, continuing presidency), Dr. D. Binnie (Manchester Metallurgical Society, following Mr. A. H. Goodger), Mr. G. H. Latham (Newport and District Metallurgical Society, continuing presidency), Mr. A. Roebuck (Sheffield Metallurgical Association, following Dr. C. Sykes, F.R.S.), Mr. B. W. Doncaster (Sheffield Society of Engineers and Metallurgists, continuing presidency), Mr. E. Marks (Staffordshire Iron and Steel Institute, following Mr. W. M. Larke), Mr. R. Griffiths (Swansea and District Metallurgical Society, following Mr. T. J. Canning), and Mr. W. Barr (West of Scotland Iron and Steel Institute, following Mr. T. M. Service, C.B.E.). Mr. W. E. Bardgett succeeded Dr. J. E. Hurst as one of the representatives of the Institution of Metallurgists, the other representative being Mr. W. W. Stevenson.

On 1st January, 1950, Professor H. W. Swift succeeded Mr. B. W. Doncaster as President of the Sheffield Society of Engineers and Metallurgists, and on 17th January, 1950, Dr. James White followed Mr. A. Roebuck as President of the Sheffield Metallurgical Association; since then they have served as Honorary Members of Council.

Dr. S. J. Kennett, President of the Liverpool Metallurgical Society, became an Honorary Member of Council on the affiliation of that Society.

In accordance with Bye-Law No. 10, the following names of Vice-Presidents and Members of Council due to retire at the Annual General Meeting, 1950, were announced at the Autumn Meeting, 1949:

Vice-Presidents—Mr. W. B. Baxter, Mr. H. H. Burton, and Mr. R. Mather.

Members of Council—Professor J. H. Andrew, Mr. N. H. Rollason, Mr. R. A. Hacking, Mr. D. F. Campbell, and Mr. I. F. L. Elliot.

No other members having been nominated up to one month before the Annual General Meeting, the retiring Members are presented for re-election.

AWARDS

Bessemer Gold Medal

The Bessemer Gold Medal for 1949 was awarded to Professor J. H. Andrew, D.Sc., in recognition of his distinguished services to metallurgy and the iron and steel industry, with special reference to the valuable research work which he had conducted or which has been

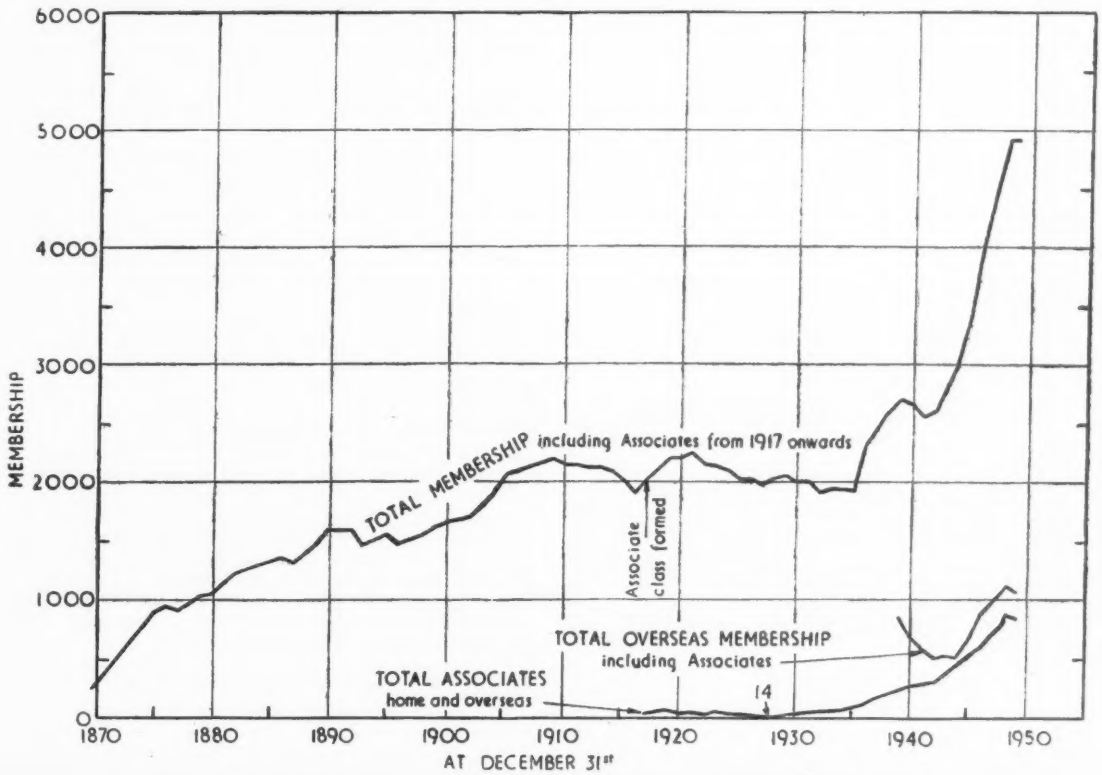


Fig. 1—Variation in membership since the foundation of the Institute in 1869

carried out under his guidance, and also in acknowledgment of his services to metallurgical education.

Sir Robert Hadfield Medal

The (Third) Sir Robert Hadfield Medal for 1949 was awarded to Mr. M. W. Thring, M.A., in recognition of his studies on the theory of heat transfer in the open-hearth furnace.

Williams Prize

The award of the Williams Prize for 1948 was reported last year.

Ablett Prize

The award of the Ablett Prize for 1948 was reported last year.

Andrew Carnegie Medal

No Andrew Carnegie Medals were awarded during 1948.

ANDREW CARNEGIE RESEARCH SCHOLARSHIPS

The following awards were made from the Andrew Carnegie Research Fund during 1949 :

G. R. BISH (University College, Swansea) : £250 for a research on the effects of cold-working on the austenite–martensite reaction during the isothermal transformation of steel.

P. L. CHANG (Sheffield University) : £250 for a research on hydrogen diffusion in steel at elevated temperatures.

H. FÖPPL (Cambridge University) : £125 for a research on the evaluation of macroscopical residual stresses in elastic solids by measuring the strains and considering their relationship in the principal axes.

H. FORD (City and Guilds College, London) : £50 to assist a research on the method of calculating roll force, torque, and mill power in cold-strip rolling with tension applied to the strip.

Miss C. MARGARETHA HYDEN (Sheffield University) : £270 for a research on the isothermal transformation of austenite.

N. H. POLAKOWSKI (University College, Swansea) : £270 (second grant) for a research on hot and cold deformation of steels and other metals.

E. T. TURKDOGAN (Sheffield University) : £250 (second grant) for a research on slag–metal reactions.

MOND NICKEL FELLOWSHIPS

The Mond Nickel Fellowships Committee made the following awards in 1949 :

J. MONAGHAN (Stewarts and Lloyds, Ltd.) : To study methods of control and administration of basic open-hearth operation and practice in the United States of America and Canada.

R. STEWARTSON (The United Steel Companies, Ltd.) : To study the design and operation of modern hot-rolling mill plant in the United States of America and Canada.

E. BRUNSKILL (Mufulira Copper Mines, Ltd.) : To study the metallurgical practice in the mining, smelting, and refining of non-ferrous metals in Africa, with special reference to copper and related metals.

The conditions governing the awards of Mond Nickel Fellowships are printed on p. 352 of the March, 1950, issue of the *Journal* (vol. 164).

The Institute continued to provide secretarial services for the Committee.

MEETINGS

Annual General Meeting

The 80th Annual General Meeting was held on 27th–28th April, 1949 ; the sessions on the first day took place at the Central Hall, Westminster, and that on the second day at the Institution of Mechanical Engineers, Storey's Gate, Westminster. The President, Sir Andrew McCance, LL.D., D.Sc., F.R.S., was in the Chair, except for the end of the meeting when Dr. C. H. Desch, F.R.S. (Past-President), deputized for him.

A buffet-luncheon was served in the Central Hall on the first day, whilst a Luncheon for Members and their guests was arranged at the Dorchester Hotel, Park Lane, London, on the second day. The proceedings are recorded on pp. 138–144 of the *Journal* for October, 1949 (vol. 163).

Autumn General Meeting

The Autumn General Meeting was held at the Offices of the Institute, 4 Grosvenor Gardens, London, on 10th and 11th November, 1949. The Chair was taken on the first day by the President, Sir Andrew McCance, LL.D., D.Sc., F.R.S., and on the second day by Dr. C. H. Desch, F.R.S. (Past-President). The proceedings will be recorded in a later issue of the *Journal*.

Special Meetings

Summer Meeting in Norway

At the invitation of the Norwegian Metallurgical Society, Oslo, and of representatives of the Norwegian metallurgical industries, Members of the Institute and their Ladies attended a very interesting and enjoyable meeting in Norway. Leaving Newcastle-upon-Tyne on 28th May, 1949, in M.S. *Venus*, which had been specially chartered, stops were made at Oslo, Kristiansand, Ålvik and Odda, Bergen, Årdal, and Balholm. In Oslo a technical session was held in the University, and the party was entertained at a reception by the Lord Mayor and Corporation, at a banquet and dance, and at a reception by His Excellency the British Ambassador. A second technical session was held on board ship in transit from Kristiansand to Ålvik. Another dinner and dance was held at Flöyen, above Bergen, and a farewell luncheon was arranged at Balholm. Works visits and excursions for the Ladies were organized from all the stopping places.

Mr. Gunnar Schjelderup was Chairman of the Main Reception Committee in Oslo, and Local Reception Committees were set up at Kristiansand, Odda, Bergen, and Årdal, and the Members and Ladies owe them, the managements of the works visited, and all who helped with the activities in Norway, a deep debt of gratitude for the warmth of their reception and the excellent arrangements which were made.

A short account of the meeting is printed on pp. 161–162 of the *Journal* for February, 1950 (vol. 164), and the discussions at the technical sessions are given on pp. 163–172 of that issue.

Discussion on the Corrosion of Steel

On 18th October, 1949, a Joint Meeting of the Institute with the British Iron and Steel Research Association was held at the Institute's offices under the chairmanship of Mr. T. M. Herbert, Chairman of the Association's Corrosion Committee. Eight papers on corrosion and corrosion-fatigue were discussed during the morning and afternoon sessions, and a buffet-luncheon was provided. The programme is given on p. 87 of the *Journal* for September, 1949 (vol. 163), and the proceedings will be recorded in a later issue of the *Journal*.

Lecture on " The Martensitic Transformation "

Dr. Morris Cohen, Professor of Metallurgy at the Massachusetts Institute of Technology, Cambridge, Pa., U.S.A., delivered a lecture on " *The Martensitic Transformation*," at the Offices of the Institute on the evening of 5th July, 1949.

FOURTH HATFIELD MEMORIAL LECTURE

At the invitation of the Council of the University of Sheffield, Sir Andrew McCance, LL.D., D.Sc., F.R.S., President of The Iron and Steel Institute, gave the Fourth Hatfield Memorial Lecture on the evening of 28th October, 1949, in the Firth Hall, Sheffield University. The subject was "*The Plastic Behaviour of Solids*" (*Journal*, 1949, vol. 163, Nov., pp. 241–249). The Vice-Chancellor of the University, Dr. J. I. O. Masson, M.B.E., F.R.S., presided.

IRON AND STEEL ENGINEERS GROUP

The Engineering Committee, which organizes the activities of the Iron and Steel Engineers Group, was composed of the following (from May, 1949):

Chairman
Mr. W. F. CARTWRIGHT

Members

Mr. J. BUCHANAN	Mr. W. J. POOL
Mr. F. B. GEORGE	Mr. L. ROTHERA
Mr. D. C. HENDRY	Mr. F. SANITER
Mr. J. F. R. JONES	Mr. B. THORNTON
Mr. G. A. PHIPPS	Mr. W. UDALL

Mr. P. WRIGHTSON

Ex-Officio

Sir ANDREW MCCANCE, LL.D., D.Sc., F.R.S. (President)
Mr. JAMES MITCHELL, C.B.E. (Honorary Treasurer)
Mr. H. H. MARDON (British Iron and Steel Research Association)
Mr. I. S. SCOTT-MAXWELL (British Iron and Steel Federation)

Three full-day meetings, with buffet-luncheons, were held at the Offices of the Institute on the undermentioned dates for the discussion of the papers listed; accounts of the meetings will be found in the issues of the *Journal* mentioned:

Wednesday, 23rd March (1949, vol. 163, Sept., pp. 81–86; Oct., pp. 207–210).
- "A Review of the Application and Design of Heavy Forging Presses," by J. A. Sanderson and J. G. Frith (1949, vol. 161, Mar., pp. 231–246).
- "Heavy Forging Manipulators," by A. V. Flinn (1950, vol. 164, Apr., pp. 463–474).
- "A Modern Heavy Forging Plant," by W. H. Alvey (1949, vol. 161, Feb., pp. 119–138).

Wednesday, 22nd June (1949, vol. 163, Dec., pp. 449–452; 1950, vol. 164, Jan., pp. 85–90).
- "Continuous Steel Strip Pickling," by R. A. Treasure (1949, vol. 162, June, pp. 201–212).
- "The Disposal of Spent Acid Pickling Liquor," by W. B. Wragge (1949, vol. 162, June, pp. 213–224).
- "The Design and Operation of Annealing Plant for Mild-Steel Sheets and Coils," by R. D. Pollard, H. Edwards, J. F. R. Jones, and J. Bromley Davis (1949, vol. 162, May, pp. 79–97).

Wednesday, 14th December (report to be published in 1950).
- "Electric Generation and Distribution in Iron and Steel Works," by T. Coxon (1950, vol. 164, Mar., pp. 327–348).
- "Protective Devices for Electrical Systems in Steelworks," by H. V. Benns and A. W. Tozer (1949, vol. 163, Nov., pp. 331–352).
- "The Layout of Integrated Iron and Steel Works," by H. H. Mardon and J. S. Terrington (1949, vol. 161, Apr., pp. 327–359).

A meeting of Junior Engineers was held at Ashorne Hill, Leamington Spa, on Wednesday and Thursday, 19th and 20th October, 1949; it was arranged jointly by the Iron and Steel Engineers Group and the Plant Engineering Division of the British Iron and Steel Research Association. The object was to provide an opportunity for the younger engineers in the iron and steel and associated industries to discuss engineering problems of mutual interest. The following subjects were discussed:

- "The Repair and Maintenance of Furnaces, with Special Reference to the Planning of Open-Hearth Furnace Rebuilds."
- "Planned Maintenance of Mechanical and Electrical Machinery in Iron and Steel Works."

On the evening of Wednesday, 19th October, an "Accidents Brains Trust" was held. Three accidents which had actually occurred were described, and members were asked to suggest suitable remedial measures for each accident; finally an account was given of the action which was in fact taken. A short report of the meeting will be found on p. 455 of the December, 1949, issue of the *Journal* (vol. 163).

PUBLICATIONS

The *Journal* was issued in twelve monthly parts, comprising volumes 161 to 163; indexes and binding cases are being prepared.

Special Reports—The following Special Reports were published during 1949:

- "Atlas of Isothermal Transformation Diagrams of B.S. En Steels," by the Thermal Treatment Sub-Committee, Metallurgy (General) Division, of the British Iron and Steel Research Association (*Special Report No.* 40)
- "Corrosion of Iron and Steel by Industrial Waters, and its Prevention," by the Industrial Waters (Corrosion) Sub-Committee, Metallurgy (General) Division, of the British Iron and Steel Research Association (*Special Report No.* 41)
- "Report on the Bessemer Process," by the Ad Hoc Bessemer Sub-Committee, Steelmaking Division, of the British Iron and Steel Research Association (*Special Report No.* 42)

Bibliography—The following Bibliography was published at the end of 1949:

- "Bibliography on the Rolling of Iron and Steel (Including References to the Manufacture of Seamless Tubes). (Covering the Period 1920 to 1947)." In two volumes (*Bibliography No.* 15)

Translation Service—Translations of twenty-four foreign technical papers (Nos. 367 to 390) were issued during 1949. The charge was £1 each (10*s.* for each additional copy of the same translation). The Council wish to take this opportunity to thank again those organizations and individuals who kindly made translations available for inclusions in the Series. A number of other translations that were unsuitable for the Series were made on behalf of Members, at their own expense.

LIBRARY AND INFORMATION SERVICE

Joint Library

The sphere of usefulness of the Joint Library continues to extend, and Members are availing themselves more and more of the organization. Increasing use has also been made of the Library by Government Departments, Research Associations, Universities, and other teaching establishments. During the past year 10,523 publications were borrowed, as compared with 10,041 in 1948. The number of textbooks added was 350, many by presentation, and the Council thank those who have presented volumes to the Library.

Members are reminded that the use of the Lending Library is a valuable privilege of membership. Books and periodicals are sent post free to Members resident in Great Britain. In addition to the books filed in the Joint Library, Members may borrow, through the Librarian, publications from the Science Library, the National

Central Library, and the Library of the Institution of Civil Engineers. Assistance is also given to Members, in Great Britain and overseas, to obtain photostat copies of articles, and these can be supplied under certain conditions. Eighty-nine photostat copies and 38 microfilms were supplied to Members during the past year. (Details of the service to the British Iron and Steel Research Association are given later.)

Information Service

The work of the Information Department is an important part of the Library service. The Department is prepared to answer Members' enquiries on the scientific and technical literature, but it is not its function to give the type of advice which comes within the field of the metallurgical consultant.

EDUCATION

Joint Committee on Metallurgical Education

Mr. E. G. Lawford agreed to become Chairman of the Joint Committee on Metallurgical Education, on the retirement, owing to ill-health, of Professor Leslie Aitchison.

During the year two Sub-Committees were formed to investigate metallurgical education at Universities and Technical Colleges.

Categories of employment have been divided into (1) managerial, (2) research, (3) technical, and (4) operatives. In considering the appropriate metallurgical training for these categories, it was decided that consideration should first be given to existing provisions in metallurgical education to see how far these were appropriate to the standard and requirements of each category.

It was decided to proceed first with the investigation into University courses, and, as a first step, enquiries were directed to the teachers of metallurgy at Universities and to a widely representative selection of employers in the metallurgical industries. Long and carefully considered replies have been received from all the Universities consulted and from over 90 individuals in industry, and these replies in many cases embody the views of several individuals and groups. They are being studied by a working party with a view to the preparation of a considered statement of the position by the appropriate Sub-Committee and the Joint Committee.

National Certificates in Metallurgy

The Joint Committee for National Certificates in Metallurgy, in which the Institute co-operates with the Ministry of Education, the Institute of Metals, the Institution of Mining and Metallurgy, and the Institution of Metallurgists, reports that satisfactory progress has been made during the year 1948–49.

Approved schemes for senior courses leading to an Ordinary National Certificate in Metallurgy were in operation at 22 Technical Colleges (compared with 18 during the previous year) and schemes for advanced courses leading to a Higher National Certificate at 11 Technical Colleges (compared with 9 during the previous year).

Final examinations for the Ordinary National Certificate were held during 1949 at 21 Technical Colleges, and for the Higher National Certificate at 10 Technical Colleges (compared with 15 and 8, respectively, during 1948). The number of candidates for the Ordinary National Certificate increased from 123 in 1948 to 221 in 1949, and for the Higher National Certificate from 38 in 1948 to 75 in 1949. There has also been a substantial increase in the number of students entering the first and second years of the courses.

Applications for approval of schemes have been received from a number of colleges, and, if approved by the Joint Committee, this will result in courses being available to students in other districts.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

The Institute continued to provide services for the British Iron and Steel Research Association and the former close collaboration was maintained. The Institute's library, information, abstracting, and translation services are freely available to the Association, and member-firms may borrow books from the Library and use the information service without charge and in their own right. The *Journal* of the Institute is the principal medium of publication for the Association's reports on its researches ; these papers, at the Association's request, receive the same scrutiny and treatment as other papers submitted to the Institute. The Institute also looks after certain matters of a more general character for the Association, such as educational activities, foreign relations, and sometimes the holding of conferences. Accounts of the Association's activities appear from time to time in the News Section of the *Journal*.

The Council are glad to record their appreciation of the close collaboration existing between the two organizations.

RELATIONS WITH OTHER SOCIETIES

The Council are pleased to report that the good relations with scientific societies and technical institutions at home and abroad have been fully maintained. This applies particularly to the Institute of Metals and the Institution of Metallurgists ; under the new Bye-Law No. 21, Ordinary and Associate Members who also belong to either of the other Societies pay a reduced annual subscription of £3 13*s*. 6*d*. and £1 11*s*. 0*d*., respectively, whilst these two Societies also make corresponding reductions in their dues payable by Members and Associate Members of the Institute.

The long-established collaboration with the Sheffield Metallurgical Association and the West of Scotland Iron and Steel Institute was continued.

Affiliated Local Societies

Towards the end of the year it was agreed that the Liverpool Metallurgical Society should become affiliated with effect from 1st January, 1950. There are, therefore, now ten Local Societies affiliated to the Institute, as follows :

Cleveland Institution of Engineers
Ebbw Vale Metallurgical Society
Leeds Metallurgical Society
Lincolnshire Iron and Steel Institute
Liverpool Metallurgical Society
Manchester Metallurgical Society
Newport and District Metallurgical Society
Sheffield Society of Engineers and Metallurgists
Staffordshire Iron and Steel Institute
Swansea and District Metallurgical Society

The object of affiliation is to enable the Institute and the Local Societies mutually to assist each other. The Local Societies retain their complete freedom of action, but agree to admit Members of the Institute to their Meetings. The Institute pays to each Local Society an annual capitation fee of 5*s*. per joint member.

Under the new Bye-Law No. 21, these Affiliated Local Societies have been declared " Kindred Societies." Those of their members who are Associate Members of The Iron and Steel Institute pay a reduced subscription to the Institute of £1 11*s*. 0*d*. per annum.

In addition to their ordinary meetings, two of the Local Societies organized Joint Meetings with the Institute during 1949 : Manchester Metallurgical Society

on 2nd February, and Ebbw Vale Metallurgical Society on 9th March.

Joint Meetings

On 12th January, 1949, the Sheffield Section of the Institution of Production Engineers arranged a Joint Meeting with the Iron and Steel Engineers Group, at the Royal Victoria Station Hotel, Sheffield, to hear a lecture by Mr. W. F. Cartwright on "*The Steel Company of Wales : Developments at Port Talbot.*"

On 15th November, 1949, the Institute of Fuel and The Iron and Steel Institute held a Joint Meeting at the Institution of Mechanical Engineers, London ; papers were read by Dr. G. E. Foxwell on "*Dry Coke Cooling,*" and by Mr. L. H. W. Savage and Mr. A. V. Brancker on "*The Application of Dry-Coke Cooling Plants to Integrated Iron and Steel Works.*" A Report by the Working Group of the Ministry of Fuel and Power was also presented.

Metallurgical Societies Overseas

Under the new Bye-Law No. 21, the seventeen Societies overseas listed below have been declared "Kindred Societies" :

American Institute of Mining and Metallurgical Engineers (Associate Member age limit, 33)
American Iron and Steel Institute
American Society for Metals
Association of Czechoslovak Mining and Metallurgical Engineers (Czechoslovakia)
Association des Ingénieurs sortis de l'École de Liège (Belgium)
Associazione Italiana di Metallurgia (Italy)
Association Luxembourgeoise des Ingénieurs et Industriels (Luxemburg)
Australian Institute of Metals
Canadian Institute of Mining and Metallurgy
Indian Institute of Metals
Instituto del Hierro y del Acero (Spain)
Jernkontoret (Sweden)
Koninklyk Instituut van Ingenieurs (Holland)
Norsk Metallurgisk Selskap (Norway)
Société Française de Métallurgie (France)
Société Royale Belge des Ingenieurs et des Industriels (Belgium)
Verein Schweizerischer Maschinen-Industrieller (Switzerland)

Members of the Institute who are members of, or are on the staffs of, member-firms of any of the above Societies, if resident in the countries concerned, pay the following reduced annual subscriptions to The Iron and Steel Institute :

Ordinary Members ...	...	£3 13*s.* 6*d.*
Associate Members ...	...	£1 11*s.* 0*d.*

Representation at Meetings

Dr. C. H. Desch, F.R.S. (Past-President) attended the centenary celebrations of the Montanistische Hochschule, Leoben, on 30th May, 1949, which were held in conjunction with the inaugural meeting of the new Austrian Metallurgical Society.

The Secretary represented the Institute at the Meeting of the Société Française de Métallurgie and the Autumn Meeting of the Institute of Metals in Paris during 3rd to 10th October, 1949, and also at the celebration of the centenary of the birth of Floris Osmond, which was organized by the Société Française de Métallurgie. Dr. Desch was also present, and agreed to represent the Institute on the Committee of Honour composed of representatives of organizations and societies to which Osmond had belonged or which had honoured him or helped in publishing his work.

During a visit to the United States of America, Sir Charles Goodeve, F.R.S., represented the Institute at a Convention of the American Society for Metals during 17th to 21st October, 1949.

PRESENTATIONS TO THE INSTITUTE

The Council desire to express their sincere thanks to Lady Invernairn for the gift of the Bessemer Gold Medal that had been awarded to Sir William Beardmore (later Lord Invernairn) in 1918, to be held by the Institute in perpetuity as a memento of her husband.

The Council are also grateful to Miss Daphne Sheila Stewart Williams and Master John Alexander Stewart Williams, who, through their aunt, Miss A. S. Williams, presented to the Institute a portrait in oils of their great-great-grandfather, Joseph Hall (1789–1862), who introduced the pig-boiling process for the production of puddled iron.

HONOURS CONFERRED ON MEMBERS

The Council warmly congratulate the many Members who have received honours or appointments during the year ; their names have been recorded in the News of Members columns of the *Journal*.

FINANCE

(*The Accounts for* 1949 *are appended*)

General Fund

Income during the year exceeded expenditure by £1,835 and there was thus a substantial improvement in the results of the year's operations compared with those of the previous year, when there had been a deficit of £2,425. The change is attributable to the increase both in the rates of subscriptions payable by Members and in other sources of revenue and to further economies which resulted in a reduction in expenditure.

Total income in 1949 was £2,173 higher and total expenditure £2,087 lower than in 1948. Total income amounted to £55,250 instead of £53,077 ; Members' subscriptions at £15,932 were £3,676 higher than in the previous year, and revenue from Publications (including Translations) at £30,079 contributed £1,093 more to the Institute's general income (£7,961 instead of £6,868) ; details are given in a separate Publications Account in which, in accordance with previous practice, salaries and overhead expenses are not charged. On the other hand, receipts from Companies' Special Subscriptions and the payment by the British Iron and Steel Research Association for services other than publishing were less by £2,133 and £1,000 respectively ; the arrangement by which certain companies subscribed towards the cost of the Institute's work has now come to an end, so that income from this source will no longer be received.

Total Expenditure amounted to £53,415 in place of £55,502. Staff expenses were less by £2,401 (£21,161 instead of £23,562) and administrative expenses were less by £351 (£4,463 instead of £4,814). Expenditure on the Library and Information Department (excluding salaries) was almost unchanged, the apparent increase of £271 (£929 instead of £658) being due to the fact that payment of fees to book reviewers and abstractors is shown separately for the first time. Expenditure on Establishment Expenses, charged against revenue, was £368 greater (£3,056 instead of £2,688) and in addition £809 was paid from Reserve for Repairs and Decorations and Office Furniture and Fittings ; the excess of Income over Expenditure on the Special Summer Meeting in Norway (£834) was not included in the Revenue for the year but was transferred to the Accumulated Fund in the Balance Sheet.

The total of the Accumulated Fund, Reserves, and Sundry Provisions, including the Life Composition Fund, was £33,302, an increase of £2,913 over the comparable figure of the previous year.

Trust Funds

In the case of the Andrew Carnegie Research Fund it was not thought necessary to make any further transfer to the Reserve for Travelling Scholarships, since no expenditure was incurred and the Reserve at £2,600 was considered to be sufficient. The amount paid or payable for grants was £1,561 (an increase of £419 on the figure for the previous year) and the balance of the Accumulated Fund carried forward was accordingly reduced from £6,214 to £5,790.

The balances of the Accumulated Funds of the Williams Prize and Bessemer Medal Funds were increased by small amounts and stood at £700 (instead of £679) and £22 (instead of £12), respectively.

Investments

The cost value at which the investments of the General and Trust Funds are taken into the respective Balance Sheets remains unchanged at £68,760, but the market value of these investments at 31st December, 1949, was £7,144 less than at the end of the previous year (£76,330 instead of £83,474).

THE IRON AND STEEL INSTITUTE

BALANCE SHEET, 31st DECEMBER, 1949

General Account

1948		LIABILITIES							1948		ASSETS			
£	£						£	£	£	£		£	£
		Accumulated Fund :									*Furniture and Fittings*		Not valued	
18,739		Balance at 31st December, 1948					18,739				*Stock of Paper*			564
		Add Excess of Income over Expenditure for the year to 31/12/49 ...					1,835		28,010		*Investments at Cost per Schedule*			28,010
		,, Surplus on Special Summer Meeting in Norway					834				(Market value at 31st December, 1949—£29,954)			
							21,408				*Sundry Debtors and Payments in Advance :*			
		Less Transfer to Reserve for Repairs, Decorations, and Equipment					1,143				Sundry Debtors		5,919	
								20,265	6,377		British Iron and Steel Research Association		354	
		Reserve :							3,035		Current Accounts		598	
		Entrance Fees Reserve :							698		Payments in advance			6,871
	5,235	Balance at 31st December, 1948					5,928		603					
	693	*Add* Transferred during year ended 31st December, 1949 ...					50		10,713		*Cash in hand and at Bank*			242
5,928								5,978	1,297		*Joint Committee on Metallurgical Education*			265
		Current Liabilities and Provisions :							144					
	11,504	Sundry Creditors (part estimated)					5,156							
	1,097	Due to Life Composition Fund					1,510							
	37	Due to Sir Robert Hadfield Legacy Fund					44							
	12	Due to Bessemer Medal Fund					22							
	471	Subscriptions in Advance					309							
	237	Payments received for Publications in advance					239							
	326	Andrew Carnegie Research Fund					329							
	47	Williams Prize Fund												
		Sundry Provisions as at 31st December, 1948 :												
	600	Reserve for Ten-Year Index					600							
	500	Library Account					500							
		Repairs, Decorations, and Equipment			666									
		Add Transfer from Accumulated Fund			1,143									
					1,809									
		Less Transfer to Repairs Account		628										
15,497	1,766	666 Transfer to Furniture Account		181	809	1,000	2,100	9,709						
								£35,952		£40,164				£35,952
£40,164														

Special Funds

1948					1948			
£	£	£	£		£	£	£	£
	Life Composition Fund :					*Life Composition Fund :*		
	Balance at 31st December, 1948	4,546				Investments at Cost as per schedule	3,449	
	Add Compounded during 1949	413	4,959			(Market value at 31st December, 1949—£4,014)		
4,546					4,546	Due from General Account	1,510	4,959
	Legacy by Sir Robert Hadfield, Bt., F.R.S.	268						
	Accumulated interest on investments	44	312			*Legacy by Sir Robert Hadfield, Bt., F.R.S.*	268	
305						(Market value at 31st December, 1949—£265)		
					305	Due from General Account	44	312
			£5,271		£4,851			£5,271
£4,851								

We have examined the above Balance Sheet of the Institute and found it to be correct.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET,
LONDON, E.C.2
March 7th, 1950

(*Signed*) W. B. KEEN & Co.,
Chartered Accountants

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1949

EXPENDITURE

1948 £	£		£	£
		Staff Expenses :		
22,296		Salaries	£19,801	
		Less Contributions from :		
150		Andrew Carnegie Research Fund	150	
212		Institution of Metallurgists	110	
100		Institute of Metals	100	
300		Joint Committee on Metallurgical Education ...	300	
500		Joint Committee for National Certificates in Metallurgy	500	
125		Mond Nickel Fellowships Committee	125	
1,387			1,285	
20,909				18,516
297		National Insurance		358
2,356		Staff Superannuation Fund		2,287
23,562		Total Staff Expenses		21,161
		Other Administrative Expenses :		
1,632		Printing and Stationery		1,049
557		Postage and Receipt Stamps		456
666		Travelling and Entertainment : General		1,026
398		Advertising		728
559		Meetings		361
432		Telephone and Telegrams		399
87		Insurances		52
147		Audit Fee—1948		147
336		Sundry Payments		245
4,814				4,463
		Establishment Expenses :		
1,200		Rent		1,200
1,409		Cleaning, Heating, Lighting, and Water		1,463
	334	Repairs and Decorations	865	
	255	*Less* Transfer from Reserve	628	
79				237
	239	Office Furniture and Fittings	337	
	239	*Less* Transfer from Reserve	181	
				156
2,688				3,056
		Publications : (*See* Publications Account)		
20,076		1949 *Journal* : Printing, Paper, etc.		20,729
485		Other Publications : Printing, Paper, etc.		1,137
789		Translations : Preparation		252
21,350				22,118
		Library and Information Department :		
658		Library : Books and Binding		613
—		Book Reviewers' Fees		94
—		Abstractors' Fees		222
658				929
53,072		*Carried Forward*		51,727

INCOME

1948 £	£		£	£
693		*Entrance Fees*	56	
693		*Less* Transfer to Reserve	50	
—				—
		Subscriptions :		
10,867		Current	15,547	
791		Companies' Nominations	17	
598		Arrears	368	
12,256				15,932
3,814		*Companies' Special Subscriptions*	570	
	337	*Less* Transfer to Entrance Fees Account	—	
	791	,, ,, ,, Subscription Account	17	
1,128				
2,686				553
		British Iron and Steel Research Association :		
6,500		Block Grant for Services other than Publications		6,000
500		*Add* Proportion of deficit for 1948	—	
7,000				
		Interest on Investments (*Gross*) :		
1,128		General Fund	1,072	
136		Life Composition Fund	141	
1,264				1,213
		Institute of Metals :		
850		Rent and Services	850	
500		Library	500	
1,350				1,350
		Publications : (*See* Publications Account)		
		1949 *Journal* :		
26,166		Revenue from Advertisements and Sales and amount payable by British Iron and Steel Research Association	27,519	
1,277		Other Publications—Sales and payments by British Iron and Steel Research Association	2,134	
775		Translations—Sales	426	
28,218				30,079
52,774		*Carried Forward*		55,127

£		£	£		£
53,072	*Brought Forward*	51,727	52,774	*Brought Forward*	55,127
	Miscellaneous :			*Special Summer Meeting in Norway :*	
1,217	Historical Investigator : Honorarium and Expenses 1,147			Excess of Income over Expenditure 834	
210	Contributions to Affiliated Local Societies 228			*Less* Transfer to Accumulated Fund 834	
	Education :				—
125	Joint Committee for National Certificates in Metallurgy ... 125				
50	Joint Committee on Metallurgical Education 50				
25	Mond Nickel Fellowships Committee 25				
200	— — 200				
	Grants :				
1	Joint Committee for Materials and their Testing 1				
25	British Standards Institution 25				
10	Mellor Memorial Fund 10				
16	Parliamentary and Scientific Committee 16				
—	Sheffield University Foundry Prize 10				
—	British Ceramic Research Association 38				
—	Association of Libraries and Information Bureaux ... 5				
25	British Refractories Research Association ... ... —				
5	Sir Robert Hadfield Plaque ... ... —				
82	— — 105				
1,709	— — 1,680				
	Adjustments for 1948 :				
	British Iron and Steel Research Association : Printing Charges not receivable 72				
	Bound Volumes—amount not fully provided 84				
	— 156				
721	*Less* Binding Cases and Index—amount overprovided 148				
	— 8		2,425	Excess of Expenditure over Income for Year	—
...	Excess of Income over Expenditure for Year 1,835				
£55,502		£55,250	£55,502		£55,250

PUBLICATIONS ACCOUNT

1949 *Journal*

EXPENDITURE

£		£	£	£
15,508	Printing, Paper, and Blocks : Text and Advertisements	16,491	17,916	
220	Bound Volumes (estimated)	255		2,974
791	Index (estimated)	675		888
450	Binding Cases (estimated)	548		1,425
2,055	Packing and Postage	2,254	5,287	
1,052	Reprints	506		
6,090	Balance transferred to Income and Expenditure Account	6,790	2,963	
£26,166		£27,519	£26,166	

INCOME

£	£	
Advertising Revenue (*Less* Reserve for Bad Debts)		18,932
Sales : *Journal*—1949 Monthly *Journals* and Bound Volumes ...	3,113	
Back Numbers	1,064	
Reprints	564	
	—	4,741
Sale of Blocks		133
Amounts payable by British Iron and Steel Research Association ...		3,713
		£27,519

Other Publications

EXPENDITURE

£		£	£
19	Bibliographies	—	1,277
345	Special Reports Nos. 40, 41, and 42	1,137	
121	Miscellaneous	—	
792	Balance transferred to Income and Expenditure Account	997	
£1,277		£2,134	£1,277

INCOME

£	
Sales and payments by British Iron and Steel Research Association ...	2,134
	£2,134

ANDREW CARNEGIE RESEARCH FUND

BALANCE SHEET, 31ST DECEMBER, 1949

1948 £	£	LIABILITIES	£	£
		Amount of Original Fund, $100,000	21,241	
5,837		*Add* Amount Capitalized per last Balance Sheet	4,596	
				25,837
		Sundry Creditors :		
850		Grants	963	
179		Travelling Scholarships		
10		Audit Fee	10	
1,039				973
		Reserve for Travelling Scholarships :		
2,500		Balance at 31st December, 1948	2,600	
500		*Add* further transfer, 1949	—	
3,000				
400		*Less* Grant during year	—	
2,600				2,600
6,214		Accumulated Fund : Balance per Account annexed		5,790
£35,690				£35,200

1948 £	£	ASSETS	£	£
33,963		Investments at Cost as per Schedule		33,963
		(Market value as at 31st December, 1949 - £38,444)		
		Cash at Bank :		
	637	On Current Account	197	
	9	On Deposit Account	9	
	534	Post Office Savings Bank Account	548	
1,180				754
221		Income Tax Recoverable		154
		Iron and Steel Institute :		
326		Current Account		329
£35,690				£35,200

ACCUMULATED FUND, 31ST DECEMBER, 1949

£		£	£	£	£
1,142	Grants	1,561	6,784	Balance at 31st December, 1948	6,214
150	Contributions to General Fund on account of Salaries	150		Income for Year ending 31st December, 1949 :	
10	Audit Fee	10	1,271	Interest on Investments	1,284
10	Printing and Stationery	—	11	Interest on Deposits	13
35	Legal Expenses	—	1,282		1,297
5	Sundry Expenses	—			
500	Reserve for Travelling Scholarships—Amount set aside	—			
6,214	Balance carried forward	5,790			
£8,066		£7,511	£8,066		£7,511

WILLIAMS PRIZE FUND

BALANCE SHEET, 31st DECEMBER, 1949

1948	LIABILITIES	£	£
£2,220	Capital Value representing Market Value of £3,000 3½% Conversion Loan on 21st September, 1926, when the Fund was inaugurated	2,220	
—	Sundry Creditor—Iron and Steel Institute	26	
679	Accumulated Fund—Balance per Account annexed	700	
£2,899		£2,946	

1948		ASSETS	£	£
£	£			
2,670		£3,452 15*s.* 7*d.* 3½% Conversion Loan at Cost (Market Value at 31st December, 1949—£3,228)		2,670
		Cash at Bank :		
	150	On Current Account	271	
	5	Post Office Savings Bank Account	5	
	155			276
	27	Income Tax Recoverable		—
	47	Iron and Steel Institute—Loan Account		—
£2,899				£2,946

ACCUMULATED FUND, 31st DECEMBER, 1949

£		£	£		£
100	Awards	100	667	Balance at 31st December, 1948	679
9	Legal Expenses			Income for year ended 31st December, 1949 :	
679	Balance carried forward	700	121	Interest on 3½% Conversion Loan	121
£788		£800	£788		£800

BESSEMER MEDAL FUND

BALANCE SHEET, 31st DECEMBER, 1949

£	LIABILITIES	£	£
400	Capital Value representing Market Value of £400 4% Debentures of the L.N.W. Railway	400	
12	Accumulated Fund—Balance per Account annexed	22	
£412		£422	

£	ASSETS	£	£
400	£474 15*s.* 0*d.* British Transport 3% Guaranteed Stock 1978/88 (Market Value at 31st December, 1949—£425)		400
12	Sundry Debtors—Iron and Steel Institute		22
£412			£422

ACCUMULATED FUND, 31st DECEMBER, 1949

£		£	£		£
3	Medal	4		Balance at 31st December, 1948	12
12	Balance carried forward	22		Income for year ended 31st December, 1949 :	
			15	Interest on British Transport Stock	14
£15		£26	£15		£26

THE IRON AND STEEL INSTITUTE

SCHEDULE OF INVESTMENTS AT 31st DECEMBER, 1949, SHOWING NOMINAL VALUES, COST AND PRESENT MARKET VALUES

Nominal Value	Nature of Security	Market Value, 31st December, 1949	Cost Value
	GENERAL FUNDS OF THE INSTITUTE		
£ s. d.		£	£
2,197 7 0	3½% War Stock	2,021	2,161
1,324 7 4	3½% Conversion Loan	1,238	1,254
2,954 1 0	4% Consolidated Stock	2,984	3,176
12,242 19 3	4% Funding Loan, 1960/90	13,039	9,512
1,000 0 0	3% Defence Bonds (P.O. Register)	1,000	1,000
2,000 0 0	3% Savings Bonds, 1955/65	1,980	2,000
2,000 0 0	Do. 1960/70	1,930	2,000
1,500 0 0	Do. 1965/75	1,418	1,500
4,854 2 0	British Transport 3% Guaranteed Stock, 1978/88	4,344	5,407
		£29,954	£28,010
	LIFE COMPOSITION FUND		
587 13 10	3½% Conversion Loan	549	513
205 15 6	3½% War Stock	189	212
681 13 0	4% Funding Loan	726	600
196 10 1	Do.	209	231
2,615 11 2	British Transport 3% Guaranteed Stock, 1978/88	2,341	1,893
		£4,014	£3,449
	ANDREW CARNEGIE RESEARCH FUND		
	(Trustees: Sir Wm. Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)		
6,897 14 11	3½% War Stock	6,346	6,896
800 0 0	Do.	736	794
2,693 12 0	3½% Conversion Loan	2,519	2,007
3,922 14 10	2½% National War Bonds, 1951/53	3,982	3,998
1,793 15 0	British Electricity 3% Guaranteed Stock, 1968/73	1,700	1,762
2,166 18 7	4% Funding Stock, 1960/90	2,308	2,643
500 0 0	2½% Defence Bonds (P. O. Register)	500	500
1,250 0 0	3% Defence Bonds (P. O. Register)	1,250	1,250
17,812 10 3	British Transport 3% Guaranteed Stock, 1978/88	15,942	10,863
1,000 0 0	3% Savings Bonds, 1955/65	990	1,000
2,250 0 0	Do. 1960/70	2,171	2,250
		£38,444	£33,963
	WILLIAMS PRIZE FUND		
	(Trustees: Sir Wm. Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)		
3,452 15 7	3½% Conversion Loan	£3,228	£2,670
	SIR ROBERT HADFIELD LEGACY		
267 11 2	3% Savings Bonds, 1955/65	£265	£268
	BESSEMER MEDAL FUND		
	(Trustees: Desmond Lysaght, The Hon. R. G. Lyttelton, and N. H. Rollason)		
474 15 0	British Transport 3% Guaranteed Stock, 1978/88	£425	—

(*Signed*) J. MITCHELL,
Hon. Treasurer

(*Signed*) K. HEADLAM-MORLEY,
Secretary

We have examined the foregoing Balance Sheets and Income and Expenditure Accounts with the Books and Vouchers of the Institute and certify them to be correct. We have also verified the balances at the Bankers and the Securities for the Investments shown above.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET, E.C.2
March 7th, 1950

(*Signed*) W. B. KEEN & Co.,
Chartered Accountants

IRON AND STEEL
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The Extension of the Ar_1 Range with Carbide Formation in Mild Steel due to High-Temperature Treatment

By J. H. Whiteley, D.Sc., F.R.I.C.

SYNOPSIS

Isolated areas containing large amounts of massive or free carbide seen in two mild-steel ingots led to some tests being made on coalescence. It was eventually found that when this steel was cooled slowly from a very high temperature, the Ar_1 range was widely extended and that the free carbide was formed directly from the residual austenite. The length of the extended range was determined by the temperature of heating above 1200° C., and the manganese content of the steel. As the latter was increased, the end of the transformation was progressively lowered until, with 1·5% of Mn, it was well below 450° C. When specimens were rapidly cooled to 1200° C. and then slowly cooled, the extension was not so great. These effects appeared to be confined to mild and low-carbon steels. The distribution of the residual austenite was always extremely uneven. Some of it could persist for very long periods, even below 550° C. When tests were repeated on a sample, the quantity of carbide produced from the residual austenite often varied considerably, and for no apparent reason. It is suggested that ferrite is the active nucleus in this carbide formation. Lastly, the S-curve for the end of the transformation was examined. When a mild steel was slowly cooled from 1430° C. the part above the knee was obviously moved well to the right, but below that point no appreciable shift was observed.

Introduction

Free Carbide in Ingot Samples

WHEN examining a subcutaneous crack in an etched section of a mild-steel ingot (sample 8, Table I) it was noticed that in two or three places massive carbide had formed in quantity, and yet, elsewhere, the margins of the pearlite grains had not been perceptibly thickened by coalescence. This local replacement of pearlite by massive, or free carbide, as it will be termed, was very striking. Such parts, in fact, could be readily found with a hand lens, as can be seen in Fig. 1*b*, where the ingot surface is at the top. Under the microscope, the darker portions of that structure appeared as shown in Fig. 1*a*. A typical area in one of the lighter patches is shown in Fig. 1*c*. Examples of the free carbide there interspersed among the pearlite are given in Figs. 1*d* and *e*. In Fig. 1*f* the area shown in Fig. 1*e* is seen after the surface had been lightly repolished and the carbide darkly stained by immersing the specimen for ten minutes in a boiling alkaline solution of sodium picrate. Figure 1*g* shows a typical area in a dark zone under a higher magnification, from which it is evident that the pearlite had not coalesced. This area also includes a part of the internal crack which was situated in a ferrite vein. Cupric etching, as well as the sulphur print shown in Fig. 1*h*, indicated that the ferrite veins occurred in a narrow band of segregate situated between columnar dendrites and, since no free carbide was present there, or in the vicinity, its formation was clearly not due to segregation. Nor was it to be accounted for by the absence of heterogeneity, for the same dendrites with their attendant coring traversed both the lighter and darker parts shown in Fig. 1*b*.

These observations led to the examination for free carbide of another as-cast mild-steel ingot. For that purpose, a horizontal slice, 3 in. wide from the outside inwards, was taken at a point near one third of the way up from the base. The analysis of the section is given in Table I, sample 4. On etching a prepared specimen 1 in. long and situated about $\frac{1}{2}$ in. from the skin, light patches similar to those in Fig 1*b* were apparent, and, again, free carbide was found in quantity in such parts, as though coalescence of the pearlite had taken place. Yet elsewhere, only very occasionally was a carbide particle to be seen, and, in this sample also, there was no thickening at the borders of the pearlite grains. A typical area in one

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Table I

DESCRIPTION AND ANALYSIS OF SAMPLES

Sample No.	Description	C, %	Si, %	S, %	P, %	Mn, %	Ni, %	Cr, %	Cu, %
1	N.P.L. pure iron	0·01	tr.	0·003	0·001	tr.	tr.	0·005	0·004
2	Armco iron	0·04	tr.	0·018	0·004	0·05	0·04	tr.	0·05
3	Steel plate 1 in. thick	0·12	0·04	0·049	0·026	0·33	0·05	0·02	0·105
4	3-ton steel ingot as-cast	0·23	0·02	0·033	0·012	0·54	0·09	0·06	0·38
5	Steel plate 1 in. thick	0·21	0·02	0·044	0·02	0·51	0·08	0·04	0·10
6	Steel plate $\frac{5}{8}$ in. thick	0·17	0·02	0·032	0·017	0·80	0·12	0·02	0·10
7	Steel plate $\frac{1}{4}$ in. thick	0·12	0·03	0·031	0·027	1·50	0·08	0·04	0·14
8	Steel ingot as-cast	0·22	0·03	0·05	0·046	0·68	—	—	—
9	3-ton steel ingot as-cast	0·47	0·16	0·046	0·033	0·78	—	—	—
10	2-ton steel ingot as-cast	0·46	0·08	0·047	0·043	0·65	—	—	—

of the lighter zones is shown in Fig. 2. The presence of the carbide there illustrated was particularly surprising, since it was known that in this instance the ingot skin had passed through the normal Ar_1 range in about 20 minutes, a period which seemed much too short for any appreciable degree of coalescence to occur in a mild steel containing 0·54% of manganese. Moreover, the macrostructure of the specimen consisted entirely of columnar dendrites, and it was to be expected, therefore, that free carbide, if caused by pearlite coalescence, would be uniformly distributed, which was far from being the case. To elucidate this matter the tendency of the pearlite to coalesce in the steel obviously required examination, and, accordingly, some tests were made on the same specimen, in which it was heated to progressively higher temperatures above Ac_3, and cooled to 630° C. at a somewhat slower rate than that at which the ingot skin had cooled.

METHOD OF HEAT-TREATMENT

The specimens were placed, either singly or in pairs, at the closed end of a silica tube 11 in. long and of $\frac{5}{8}$ in. internal diameter, together with about 0·1 g. of drillings from a 2·0% carbon-steel bath sample, by which means any noticeable change in the carbon contents was avoided. The open end of the tube was then closed with a rubber cork through which passed a short piece of glass tubing, and after the end had been made gas-tight with picene wax, it was connected with an Arnolds' potash bulb containing a little water. When specimens were to be heated to temperatures below 1300° C., the tube was inserted, for about one half of its length, in a platinum-wound furnace, and for higher temperatures a Silit rod furnace was used. At the commencement of the cooling stage in a test, the rubber tube leading to the Arnolds' bulb was clipped.

Temperatures were taken by placing a Pt/Pt–Rh thermocouple beside the end of the silica tube and, when cooling below 1050° C., the same equipment was always used, the galvanometer readings being occasionally checked with a Cambridge potentiometer. The finishing temperatures recorded in the paper may therefore be regarded as strictly comparable. According to these instruments, the normal Ar_1 transformation in mild steels containing 0·50 to 0·60% of manganese began at about 700° C., and ended at about 675° C. That was ascertained by examining specimens quenched at temperatures below 710° C., after they had been slowly cooled from between 1050° and 1150° C., the rate of fall through the Ar_1 range being approximately 1° C./min. It should be mentioned that the above upper limit at 700° C. is several degrees lower than that sometimes quoted. Mehl,[1] for instance, seems to consider that, under a prolonged isothermal treatment, pearlite starts to form at 725° C.

Occasionally during the investigation, quenched specimens were tempered, usually at about 350° C., in order to convert to a darkly etching troostite any martensite that might be present for, being embedded in ferrite, its structure was often difficult to develop satisfactorily for illustration. To obtain a non-tarnishing atmosphere, so that there was no need to repolish the surface before etching again, the following simple method was adopted : A quantity of the high-carbon steel drillings was placed at the closed end of a silica tube and the specimen was placed at the corked end. Having made the tube gas-tight with picene wax, it was inserted in a furnace at about 1000° C., and after a few minutes the rubber tubing attached to the bung was clipped. The tube was then kept at or near this temperature for 3 hr., when it was withdrawn and, as soon as the drillings had cooled to about room temperature, the specimen was dropped in, whereupon the tube was at once placed for 10 min. in another furnace standing at the tempering temperature. The etching reagent used throughout the investigation was a saturated solution of picric acid in 98% alcohol, and the quenching medium was cold water.

EXAMINATION OF COALESCENCE

The first coalescence test on the specimen from sample 4 (p. 399) was made by heating it for 10 min. at 950° C., cooling in 2 hr. to 630° C., and quenching at that temperature. The surface was well ground, re-prepared, etched, and carefully traversed under a magnification of 250 diameters. Although the rate of cooling through the Ar_1 range had been slower than that of the ingot skin, in only a few areas was any carbide found, and none contained more than that shown in Fig. 3*a*. A second test was then made in which the procedure was precisely the same, except that this time the specimen was heated to 1200° C. Again no appreciable coalescence was to be seen ; in fact, its degree was distinctly

less than in the previous test, where the grain size was smaller. Nowhere was the amount larger than that shown in Fig. 3*b*.

Since carbide formations of the kind originally present had not so far been produced, a further test was made in which the same specimen was heated to a temperature much closer to the point of incipient fusion, thereby approaching more nearly the cooling range of the ingot. The procedure was as follows : The specimen, contained in a silica tube, was inserted in a furnace at 1100° C., and the temperature was raised in 30 min. to 1430° C., after which it was gradually reduced, again in 30 min., to 1200° C. At 1150° C., a few minutes later, the tube was quickly transferred to a Nichrome-wound furnace standing at 1050° C. ; this change being made for better control of the subsequent cooling during which a temperature recording instrument was used. The temperature was then lowered in about 3 hr. to 630° C., when, as in the previous tests, the specimen was quenched. It should be noted that all the very high-temperature tests mentioned in the paper were conducted in this way, so that, when specimens in such tests are said to have been slowly cooled, it will be understood that the rates above and below 1200° C. approximated to those given in this test.

Again, almost no free carbide was obtained ; if anything, the degree of coalescence was even less than in the 1200° C. test. But a feature entirely unexpected was the presence in a few places of some grains of martensite of the type produced by well quenched hyper-eutectoid steels, as shown in Fig. 4*a*. It was thus evident that the whole of the austenite had not transformed, although the slowly reached quenching temperature was at least 40° C. below the end of the normal Ar_1 range.

The question then arose as to whether the free carbide could be formed directly, at a still lower temperature, from this retained austenite. In order to find out whether that was the case the following test was made. Two specimens from the ingot sample 4, both containing some free carbide, were heated together, in separate tubes, to 1430° C., after which they were slowly cooled to 630° C., when one was quenched, while the other was further cooled in 2 hr. to 500° C., and quenched. Again, in the 630° C. specimen, grains of martensite were seen in a few places, usually wide apart, and again there was no free carbide. In the specimen cooled to 500° C. however, that constituent had at last been produced. It was present in quantity in three areas, one of which is shown in Fig. 4*b*. As no martensite was apparent in this specimen there could be little doubt that the carbide had been derived from the austenite remaining at 630° C.

Occasionally, the carbide had been precipitated as a set of needles, or else plates, in the manner shown in Fig. 1*d*. One such group is illustrated in Fig. 4*c*, which shows an area in the polished specimen after it had been immersed for 10 min. in boiling sodium picrate. The same area is again shown in Fig. 4*d* when the surface had been lightly repolished and etched. Since it was obvious, on comparing the area with Fig. 4*c*, that two or three small particles had not been darkened by the picrate, the specimen was then tempered at 350° C., lightly repolished, and again etched, with the result shown in Fig. 4*e*. The unstained particles had been converted to darkly etching troostite, thus clearly demonstrating that, even at 500° C., notwithstanding the very slow cooling, a little austenite still remained, although it had not been detected as martensite when the untempered specimen was examined.

EFFECT OF MANGANESE CONTENT

As so wide an extension of the Ar_1 range had been obtained in this steel by the very high-temperature treatment with, as a consequence, a formation of free carbide, it appeared worth while to ascertain what influence manganese had on these effects, and accordingly a series of unsegregated samples was taken in which the manganese content increased from nil to 1·50%. The analyses of these samples, together with those of other steels used in the investigation, are given in Table I.

Trace of Manganese—Two specimens of sample 1 were first carburized in Hardenite for 5 hr. at 930–950° C. They were then removed and heated in a closed silica tube for 18 hr. at 1000° C., air-cooled, and examined. From the amount of pearlite now present in them, it was judged that the required quantity of carbon, about 0·20%, had been introduced. One of the specimens was then inserted in a furnace, at 1100° C., and gradually heated to 1430° C. in 90 min. ; this long period being given in order to ensure a uniform carbon distribution. After the usual slow cooling, the specimen was quenched at 635° C. No martensite could be discovered in it, but in a few places particles of free carbide appeared, similar to those shown in Figs. 1*e* and 2, although elsewhere only a slight coalescence had taken place at the borders of the pearlite grains.

A similar test was then made on the other carburized specimen. It was heated to 1430° C., while the specimen already used was kept at the cold end of the tube and dropped in when the temperature had fallen, in the slow cooling, to 1150° C. The quenching temperature this time was 660° C. In the 1430° C. specimen martensite was now clearly present, and, in the areas where it occurred, there was also some free carbide of the kind observed in the previous test. An area containing these two constituents with the surrounding pearlite grains is shown in Fig. 5*a*. The same area is shown in Fig. 5*b*, after the specimen had been tempered at 350° C., and re-etched. In the specimen dropped in at 1150° C. no martensite was to be seen, and free carbide was not encountered. Another difference was that the degree of pearlite coalescence was considerably greater than in the 1430° C. specimens. With the object of locating more nearly the lower end of the normal Ar_1 range in this material, one further test was made in which the 1150° C. specimen was reheated to 1000° C., cooled at a somewhat faster rate, and quenched at 680° C. It then had about the same amount of martensite as the 1430° C. specimen quenched at 660° C. Thus, the indications were that the transformation range in this carburized pure iron, when slowly cooled from 1430° C., was not widened more than about 20° C.

0·05% *of Manganese*—Some specimens of sample 2 were first similarly carburized to approximately 0·25%. Two of them, in separate tubes, were then heated together during 90 min. from 1100° C. to 1430° C., slowly cooled, and quenched respectively at 700° and 635° C. In the 700° C. specimen a little pearlite had formed, thus showing that the Ar_1 range had been entered. Among the slightly coalesced pearlite grains in the 635° C. specimen, patches of free carbide occurred, of the type shown in Figs. 1*d* and *e* and Fig. 2. In two or three of those places a small white particle was observed which proved to be martensite, for, after tempering the specimen at 350° C., these particles etched very darkly. The test was then repeated with quenching temperatures of 655° and 645° C. In the 645° C. specimen, one or two quite large grains of martensite were now to be seen, and in the 655° C. specimen that constituent was present in quantity ; an area containing several grains is shown in Fig. 6. Lastly, the 645° C. specimen was reheated to 1000° C. and, after a slow cooling, was quenched at 665° C., in order to ensure that the normal Ar_1 range ended above that temperature. As was expected, the transformation had been complete, for no martensite could be found. It was concluded, therefore, that when this carburized iron was slowly cooled from 1430° C., its Ar_1 range was extended at least 40° C.

0·33% *of Manganese*—Firstly, a specimen of sample 3 was heated to 1430° C., slowly cooled, and quenched at 675° C., another specimen being dropped in from the cold end of the tube at 1200° C. In the latter specimen the Ar_1 range had evidently been passed, for the eutectoid grains had been entirely converted to pearlite. In the 1430° C. specimen that was not the case, since numerous martensite grains were present. Further tests were then made in which specimens were slowly cooled from 1430° C., and quenched at temperatures below 675° C. At 630° C., martensite was still to be seen in several areas, one of which is shown in Fig. 7*a*. Nor had the martensite completely disappeared in a specimen quenched at 600° C. However, in another, quenched at 570° C., none could be detected. It was thus clear from these results that the very high-temperature treatment had widened the Ar_1 range in this steel by more than 70° C. In all the specimens quenched below 650° C. free carbide, similar to that shown in Figs. 1*d* and 1*e*, had formed, often in quantity, and yet the pearlite grains were never more than narrowly bordered with cementite. In areas where martensite occurred some free carbide usually accompanied it, as is shown in Fig. 7*a*.

0·51% *of Manganese*—A similar set of tests was carried out on sample 5, the manganese content of which was about the same as that of the ingot sample 4. In the first test, two specimens were slowly cooled, one from 1430° C., the other from 1200° C., and quenched at 665° C. On examination, no martensite could be found in the 1200° C. specimen, showing that the normal Ar_1 range ended above 665° C., whereas in the 1430° C. specimen there was rather more martensite than pearlite.

Tests were then made in which specimens were slowly cooled from 1430° C., and quenched at progressively lower temperatures. In the specimen quenched at 630° C., martensite was to be seen in quite a number of places, as was the case in the same test on the ingot sample 4. At 590° C., a few areas still contained that constituent, one of which is shown in Fig. 7*b*. Even at 570° C., several small martensite grains were present in the specimen. Evidently, therefore, by slowly cooling this steel from 1430° C., its Ar_1 range had been extended by at least 100° C. Although in these tests coalescence of the pearlite was, at most, only slight, typical free carbide began to appear at 630° C., often with the martensite, whereas no free carbide could be discovered in two specimens which had been heated to 1000° and 1200° C. respectively, and slowly cooled to 500° C.

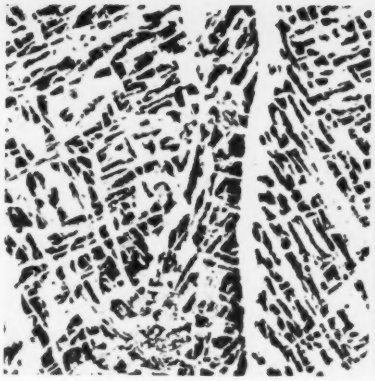
0·80% *of Manganese*—The same order of procedure was again followed with sample 6. A specimen was heated to 1430° C., slowly cooled, and quenched at 670° C., a temperature just above the end of the normal Ar_1 range in this steel. On examination, it was found that while some pearlite had formed, martensite predominated. Another specimen was then slowly cooled from 1430° C. and quenched at 630° C. Again, a quantity of martensite was present, although there was less than in the previous test. As the quenching temperature was further lowered the amount continued to diminish, but even at 550° C. several martensite grains were to be seen in the specimen, notwithstanding that it had been cooled from 600° C. at a rate of less than 1° C./min. Slow cooling from 1430° C. had, therefore, widened the Ar_1 range by at least 120° C.

Not the smallest degree of coalescence appeared at the margins of the pearlite grains in any of these tests, and yet below 630° C. free carbide began to occur. The amount was never large, however, even when the transformation was virtually complete.

1·5% *of Manganese*—On sample 7, only three tests were made, but they sufficed to show that the Ar_1 range in this steel, when slowly cooled from 1430° C., was extended more than 150° C. The specimens were quenched at 570°, 500°, and 450° C., the rate of cooling below 600° C. being approximately 1° C./min. In the specimen quenched at 570° C. martensite was the main constituent, and at 500° C. about one-tenth of the austenite had not transformed. One area containing several large grains of martensite is shown in Fig. 8*a*, and again in Fig. 8*b*, after the specimen had been tempered at 400° C. No free carbide was encountered in either specimen. Even at 450° C. an appreciable quantity of austenite had remained. In that specimen, however, a little free carbide was found and, as often happened, it was in needle form. This is shown in Fig. 8*c*, the polished specimen having been treated with the sodium picrate reagent. Figure 8*d* shows the same area after the specimen had been lightly etched. Some particles were present which had not been darkened by the picrate and, to make certain that they were martensite, the specimen was tempered at 450° C., repolished, and again etched. The area after this treatment is shown in Fig. 8*e*. Not the slightest amount of coalescence had taken place in any of the three specimens.

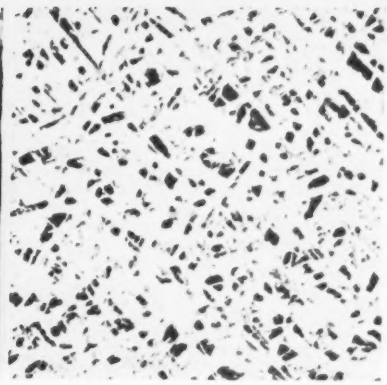
Discussion of Results

The results obtained in this series of tests thus showed that the Ar_1 range in mild steel, slowly

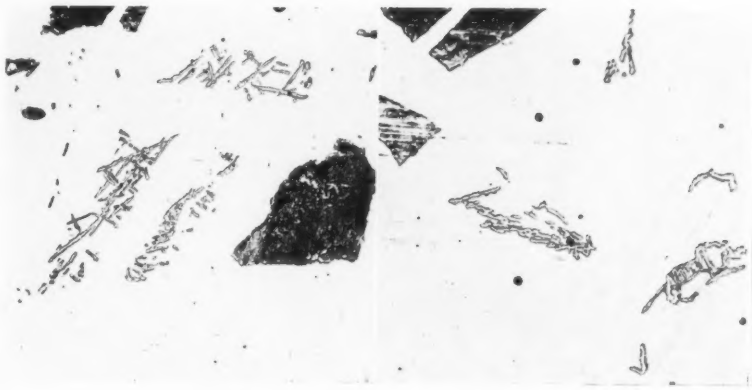


(*a*) Typical dark area × 35

(*b*) Light and dark areas ; ingot surface at top × 2·5



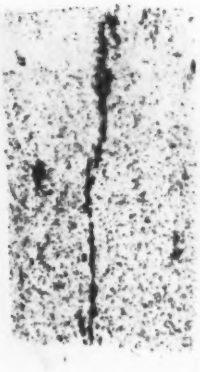
(*c*) Typical light area × 35



(*d*) and (*e*) Free carbide in light areas × 370

(*f*) Area shown in (*e*) after light repolishing and sodium picrate staining × 370

(*g*) Dark area with a central ferrite vein × 170



(*h*) Sulphur print ; ingot surface at top × 2·5

Fig. 1—Specimen of mild-steel ingot, as-cast; etched × 35

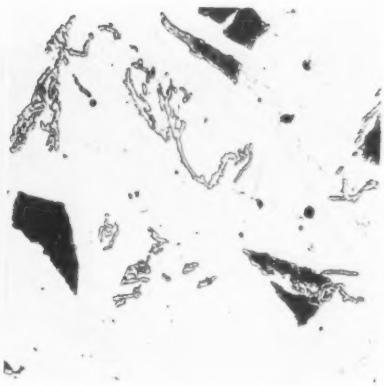
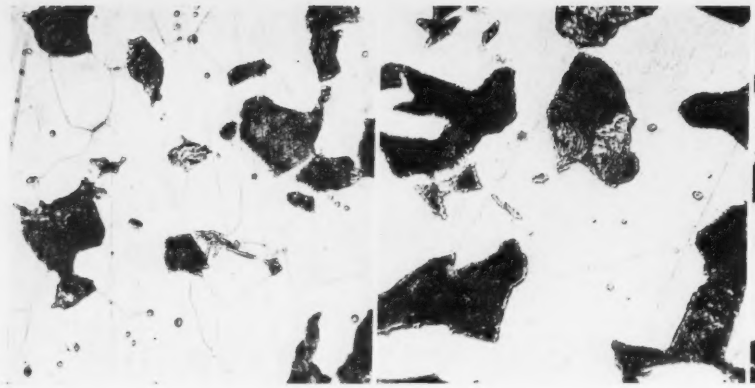


Fig. 2—Free carbide in light area in a specimen of a 3-ton as-cast mild-steel ingot × 330



(*a*) Slowly cooled from 950° C. (*b*) Slowly cooled from 1200° C.

Fig. 3—Pearlite and carbide in a specimen from a 3-ton as-cast mild-steel ingot × 250

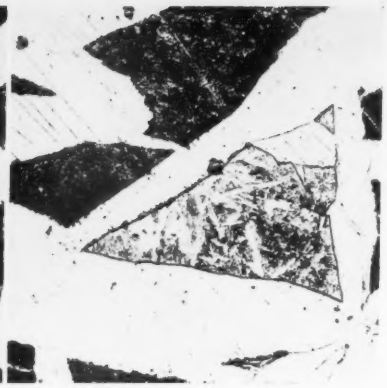
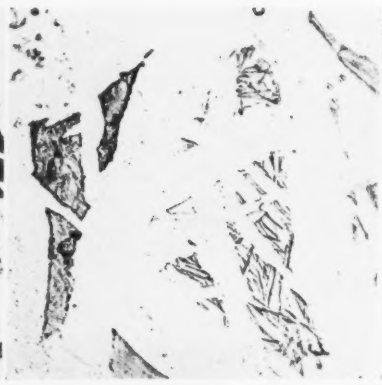
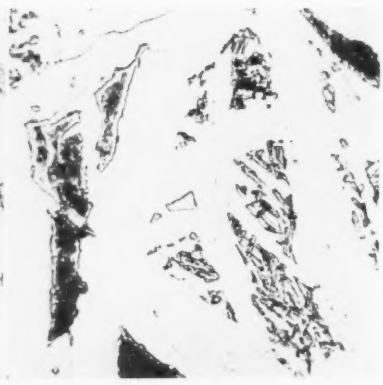


Fig. 4(*a*)—Martensite and pearlite, after quenching at 630° C. × 270

(*b*) Carbide and pearlite, after quenching at 500° C. × 95



(*c*) Carbide, after quenching at 500° C. and staining with sodium picrate × 330



(*d*) Area shown in (*c*) after light repolishing and etching × 330

Fig. 4—Specimen of 3-ton as-cast mild-steel ingot ; heated to 1430° C.

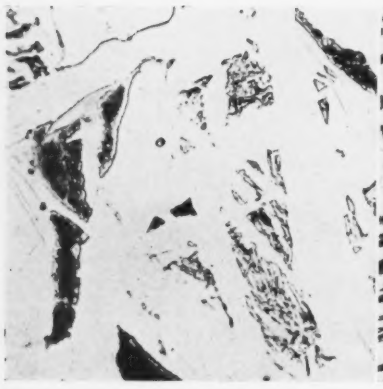
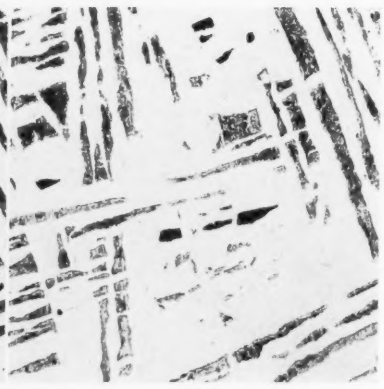


Fig. 4(*e*)—Area shown in (*c*) after tempering at 350° C. and etching × 330

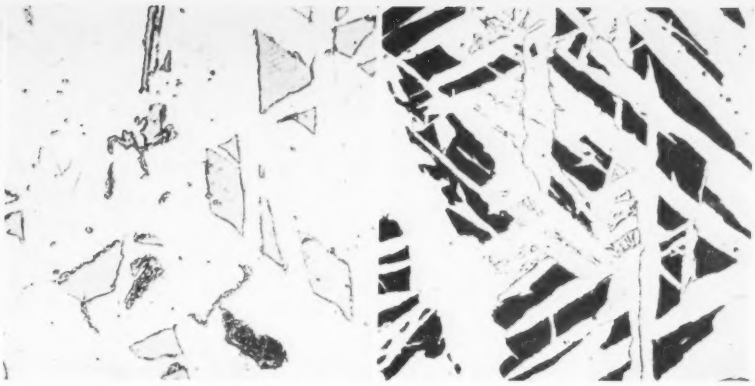
(*a*) Martensite and carbide surrounded by pearlite



(*b*) Area shown in (*a*) after tempering at 350° C. and etching

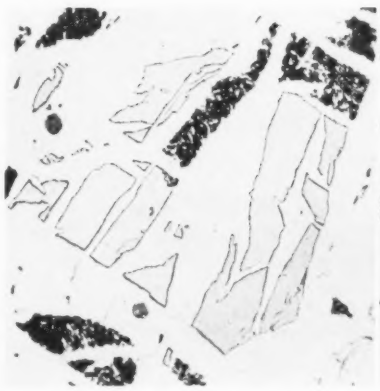
Fig. 5—Pure iron, carburized, heated to 1430° C., slowly cooled, and quenched at 660° C. × 95

Fig. 6—Martensite and pearlite in iron (0·05% of Mn), carburized, heated to 1430° C., slowly cooled, and quenched at 655° C. × 180



(*a*) × 370 (*b*) × 95

Fig. 7—Specimens heated to 1430 C., slowly cooled, and quenched: (*a*) Sample 3 (0·33% of Mn) at 630° C.; (*b*) sample 5 (0·51% of Mn) at 590° C.

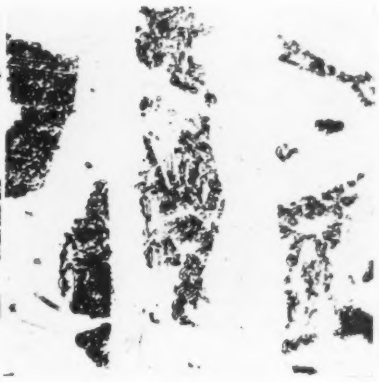


(*a*) Quenched at 500° C. Martensite grains and pearlite × 370

(*b*) Area shown in (*a*), tempered at 400° C., picric etched × 370

(*c*) Quenched at 450° C., sodium picrate etched. Needle-like free carbide grains × 650

(*d*) Area shown in (*c*) after light etching × 650



(*e*) Area shown in (*c*) after tempering at 450° C. and re-etching × 650

Fig. 8—Sample 7 (1·5% of Mn) heated to 1430° C., slowly cooled, and quenched at different temperatures

Fig. 9—Sample 5 heated to 1430° C., and air-cooled from 630° C. × 250

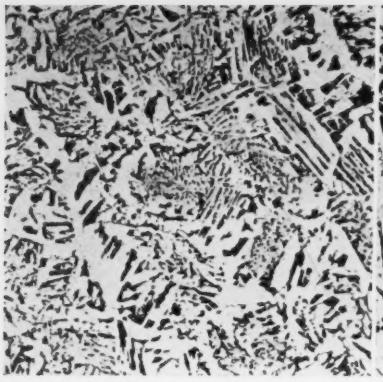


Fig. 10—Sample 5 heated to 1430° C., and cooled quickly to about 1050° C. × 30

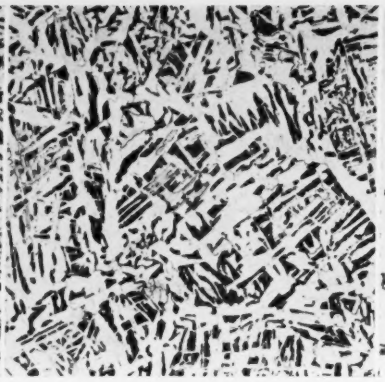


Fig. 11—Sample 5 heated to 1430° C., and slowly cooled × 30

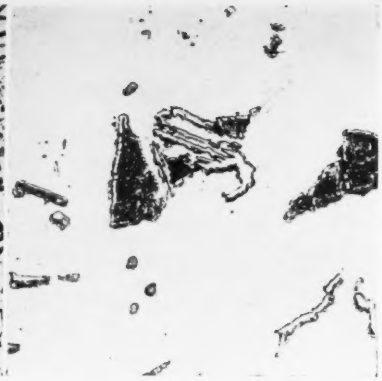
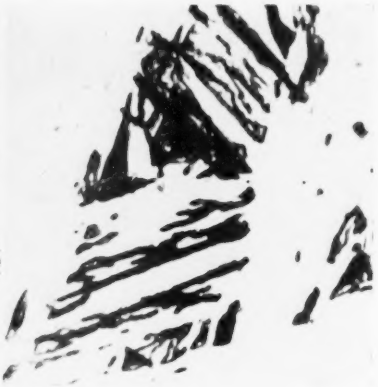


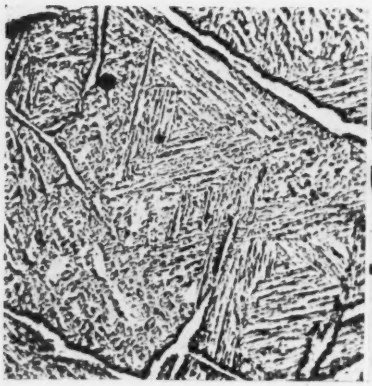
Fig. 12(*a*)—Quenched at 500° C. Free carbide with pearlite × 520

(*b*) Quenched at 570° C., picric etched. Ferrite separation in austenite grains × 1500

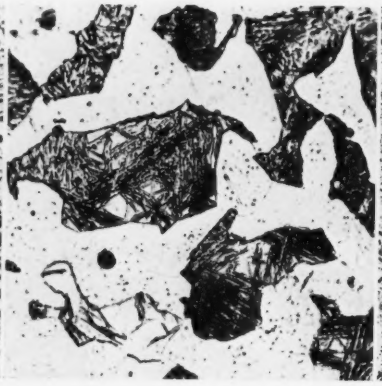
(*c*) Area shown in (*b*), sodium picrate etched × 1500



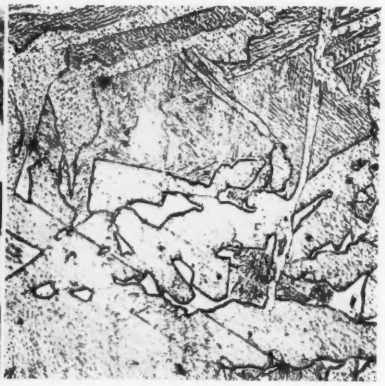
(*d*) Area shown in (*b*), tempered at 350° C. picric etched × 1500



(*e*) Quenched in solder at 350° C. × 330



(*f*) Quenched in solder at 305° C. × 330



(*g*) Quenched in solder at 250° C. × 250

Fig. 12—Sample of 3-ton as-cast steel ingot, heated to 1430° C., quenched at different temperatures, and slowly cooled

cooled from 1430° C., was increasingly widened, and to a remarkable extent, as the manganese content was raised. No attempt was made to determine the precise point at which the last of the austenite was transformed in each sample. There were indications that it could vary somewhat, depending perhaps on the length of heating, but, judging by the way the martensite diminished as the quenching temperature was lowered, the temperatures at which the austenite virtually disappeared would not be far from those stated in the third column of Table II.

The tests also provided strong evidence that the formation of free carbide was not due to pearlite coalescence, but was in some way a consequence of the extension of the Ar_1 range. Now, since the ingot samples in which this carbide had first been observed had not been heat-treated, it was inferred that a similar lengthening of the range took place when mild steel was slowly cooled from the liquid state. To confirm this the following test was made : A section of sample 6, about 25 g. in weight, was placed in a Pythagoras tube, 11 in. long, and, after closing the open end as described on p. 400, the tube was inserted vertically in a Silit rod furnace at 1000° C. The temperature was then raised in 20 min. to 1580° C., after which it was lowered in 15 min. to 1430° C., from which point the procedure was the same as in the 1430° C. tests. At 570° C., the tube was withdrawn, and the hot end was at once broken under water to quench the small ingot within. A manganese determination was then made, when it was found that remelting had reduced the content from 0·80% to 0·35%. Nevertheless, a few grains of martensite were to be seen in a prepared section, and some free carbide was also present, although the pearlite had not coalesced appreciably.

An outstanding feature of the austenite grains, in the 1430° C. tests, was the wide differences between the periods through which they persisted in a specimen when it was well within the extended Ar_1 range. In some parts these grains transformed almost as soon as the range was entered, whereas in other parts many would remain unchanged for a very long time, even when the temperature was relatively low and stationary, as the following test clearly showed : Two specimens from sample 4 and two from sample 6 were heated together in pairs to 1430° C. and slowly cooled to 630° C., when one pair, consisting of a specimen from each sample, was quenched. The other pair was held for 4 hr. at that temperature before being quenched. Both of those specimens still contained a considerable amount of martensite, although somewhat less than the quantity in the respective specimens quenched at once.

The persistence of some of the supersaturated austenite grains was also seen when specimens were air cooled instead of quenched. In one such test, specimens from samples 5 and 6 were heated to 1430° C. and slowly cooled to 630° C. At that point, a bare thermocouple was inserted in the far end of the tube, which was then withdrawn from the furnace. As the specimens cooled, the temperature drop was noted. It fell from 630° to 400° C. in 70 sec., to 300° C. in $2\frac{1}{4}$ min. and to 150° C. in $5\frac{1}{4}$ min. ; a rate that would have allowed ample time for a complete transformation, had the specimens been heated only to 1200° C. and air cooled from 710° C. But the transformation was by no means complete, for in both specimens many grains of martensite with but slight borders of troostite were found. In Fig. 9 can be seen some of the smaller grains in various stages of decomposition.

Another noteworthy feature of the austenite remaining below the normal Ar_1 range was the very marked irregularity of its distribution. It was therefore necessary to traverse the whole of the prepared surface when estimating the amount of martensite in a specimen. This very definite localization of the residual austenite, like that of the free carbide in the two ingot samples, could not be attributed to a lack of homogeneity, for no heterogeneity could be detected in the specimens after their very high-temperature treatment. The possibility that an uneven manganese content was the cause should not be overlooked, however, since Betteridge and Sharpe[2] have advanced evidence that manganese may not always be in completely uniform solid solution, even when other elements are in that state.

Table II

APPROXIMATE TEMPERATURES TO WHICH THE AR_1 RANGE WAS EXTENDED IN SAMPLES SLOWLY COOLED FROM 1430° C.

Sample No.	Manganese, %	Virtual End of Ar_1 Range, °C.	Approximate Extension Beyond the Normal, °C.
1	tr.	650	20
2	0·05	630	40
3	0·33	590	80
5	0·51	560	110
6	0·80	530	130
7	1·50	400	200

EFFECT OF INITIAL RATE OF COOLING TO 1200° C.

To determine whether the extension of the Ar_1 range was affected by the initial rate of cooling to 1200° C., some of the 1430° C. tests on samples 3–7 were made on two specimens, one of which was slowly cooled and the other rapidly cooled. A test was always taken in which the amount of martensite in the slowly cooled specimen would be sufficient to make easily observable any difference in the one quickly cooled. The specimens were heated in separate tubes. At 1430° C., one of the tubes was withdrawn and its hot end was at once dipped intermittently in water until, in about 5 sec. the temperature of the specimen was near 1100° C. The tube was then inserted in a furnace standing at 1050° C., to await the other specimen, and when the two had been slowly cooled to the selected temperature, they were quenched. In every instance, it was found that the specimen slowly cooled from 1430° C. contained more martensite than the one quickly cooled. Usually, only an odd grain or two of that constituent was to be seen in the latter, as against a relatively large quantity in the former. The rapid cooling to below 1200° C. had, therefore, caused a contraction of the Ar_1 range towards the normal, but whether a still faster cooling would have resulted in a further rise of the lower limit was not ascertained. Nevertheless, it was evident that the rate of temperature drop during

the early cooling stage was a factor in the extension. In passing, it should be remarked that the Widmanstätten structure in the quickly cooled specimens was never very pronounced. In them, a formation of the kind shown in Fig. 10 predominated, whereas in the slowly cooled specimens the Widmanstätten structure was always prominent. Figure 11 provides an example.

EFFECT OF HEATING TEMPERATURE

During the investigation two tests were made in which specimens from sample 6 were slowly cooled from 1360° C., instead of from 1430° C., and quenched respectively at 600° and 620° C. In the 600° C. specimen, free carbide occurred in quantity, but there was no martensite, whilst the 620° C. specimen had about the same amount as the 570° C. specimen of the steel in the 1430° C. tests. This indicated that the extension of the Ar_1 range receded gradually until it became normal, as the temperature of heating was lowered ; in other words, there was no point above 1200° C. at which a sudden change in the length of the range was induced.

Although, for convenience in description, the term martensite has been used throughout to denote the constituent which was austenite at the time of quenching, that designation was probably not always correct. In specimens quenched from above 600° C. martensite could generally be readily identified, since etching revealed its characteristic structure, as can be seen in Fig. 4*a*. The farther the quenching temperature was below that point, however, the more difficult it became to develop a distinct structure in such grains. Also, scratch tests seemed to show a progressive softening of the constituent, probably owing to an increasing carbon content. Possibly, therefore, a concentration was reached at which no martensite was formed in the austenite, so that it remained unchanged in the quenched specimen.

Formation of Free Carbide

In the 1430° C. tests described on p. 402 free carbide did not begin to appear in the mild-steel specimens until the quenching temperature was reduced to below 650° C., and it then continued to be deposited up to the end of the transformation, a finding that was certainly not anticipated. Hence, this carbide must be distinguished from massive cementite resulting from pearlite coalescence, which takes place well above 650° C. Likewise, in support of this view was the fact that, in the 1430° C. tests on samples 4, 5, and 6, very little or no coalescence had occurred at the margins of the pearlite grains and yet, in some areas, free carbide was present in quantity. Carbide due to coalescence is not confined to a few places but is distributed fairly uniformly when segregation is absent. Again, on repeating some of the 1430° C. tests, it was found that a constant amount of free carbide in any one sample could not be depended on, even in cases where the transformation was virtually complete. This also tended to confirm the above conclusion, for the degree of coalescence varies but slightly, if at all, when the treatment is the same.

An extrapolation of the Ar_3 curve in the iron–carbon equilibrium diagram indicates that, as the temperature falls below the Ae point, the carbon still held in solid solution rapidly increases in amount. Yet, even so, the formation of the free carbide must be due to some other factor besides carbon concentration, for, in the two samples low in manganese, it began to appear at temperatures not far below the normal Ar_1 range, where the degree of supersaturation would be relatively small. Also, the residual austenite did not always give free carbide ; some of it transformed to pearlite. In fact, the two processes were found to overlap, for, when examining the 1430° C. test specimens, quenched well below the normal Ar_1 range, a grain was occasionally encountered in which pearlite was in process of growth at the time of quenching, although some free carbide had already been deposited. Instances were also observed where an austenite grain had decomposed into both pearlite and carbide ; an example is given in Fig. 12*a*, where a heavy coalescence appears to have occurred. But that was obviously not so, since elsewhere no pearlite grain could be discovered with even the slightest border of cementite except, of course, in the few areas similar to that from which the above illustration was taken. When such areas were present, they invariably contained one or more particles of carbide, besides that associated with the pearlite ; two or three can be seen in Fig. 12*a*.

The above observations all tended to show that the problem of free carbide formation was mainly one of nucleation, secondary factors being the carbon and manganese contents of the austenite. According to Mehl,[1] cementite nuclei start the growth of pearlite, and the suggestion is now made that ferrite is the active nucleus for free carbide. The process often seemed to begin with a deposition of extremely thin ferrite layers along the cleavage planes in the austenite grain, and these layers widened until either carbide was precipitated, or a residue was left which was presumably also a carbide, since it too was darkened by sodium picrate.

To illustrate this initial ferrite separation, an example was selected from a specimen of sample 5, quenched at 570° C. in the 1430° C. tests. It is shown in Fig. 12*b*, with the prepared surface very lightly etched. Apparently the area contained both martensite and free carbide. To confirm the presence of the latter, the specimen, as etched, was boiled for 10 min. in the sodium picrate reagent. The result is shown in Fig. 12*c*. The specimen was then tempered at 350° C., and without repolishing either before or after that treatment, the surface was again etched. The area as it now appeared is shown in Fig. 12*d*. Evidently the grains near the centre had been austenite at the time of quenching, and had the lines of ferrite in them been allowed to widen, there can be little doubt that, eventually, free carbide either would have been precipitated in an irregular shape, or would have ultimately formed plates similar to those at the sides.

EFFECT OF CARBON CONTENT

Having produced the free carbide first observed in the two mild-steel ingots, two medium-carbon ingots, samples 9 and 10, were examined in order to see whether the same type of carbide occurred in them.

Specimens prepared from both the columnar and axial zones were etched and inspected with a hand lens, but they exhibited no light areas such as those shown in Fig. 1*b*. The absence of any quantity of free carbide was thus inferred, and was fully confirmed when the surfaces were traversed under the microscope. A test was then made in which specimens from the columnar part of each ingot, together with one from sample 3, were slowly cooled from 1430° C. and quenched at 640° C. Again, no free carbide was to be seen in the ingot specimens, nor was any martensite present. All the eutectoid grains had transformed to a well-defined and uncoalesced pearlite, while not more than four-fifths of the austenite had changed to pearlite in the specimen from sample 3, where, besides many grains of martensite, there was also a little free carbide. Apparently, therefore, an extension of the Ar_1 range by very high-temperature treatment, with consequent carbide formation, is confined to mild and low-carbon steels ; in other words, a considerable amount of pro-eutectoid ferrite seems to be needed before those effects can be obtained.

EXAMINATION OF THE S-CURVE

From the results given by the 1430° C. tests, it was clear that the upper part of the **S**-curve, representing the end of the transformation in mild steel, had been moved well to the right, but they provided no evidence that the lower portion was similarly shifted. Therefore, to arrive at some idea of what happened below the knee of the curve, a few more tests were made on sample 5, in each of which the procedure was as follows :

A specimen was heated to 1430° C. and cooled in 30 min. to 1200° C. At that point, another specimen was dropped in from the cold end of the tube, and the slow cooling was continued. When 720° C. was reached, the two specimens were quickly immersed in molten solder, standing at a temperature which ranged from 350° to 250° C., and, after remaining there for 2 min., they were quenched in water. Their structures were then compared, and in every instance they were found to be essentially the same, the only marked difference being in the grain sizes.

In the specimen quenched from 350° C., the austenite had been completely converted into a needle-like constituent, resembling the martensite produced when mild steel is quenched from above the Ac_3 point, except that it was softer, and had a light brown colour when etched, Fig. 12*e*. Presumably, martensite had formed at 350° C., and had then been slightly tempered. It was, however, quite unlike the type shown in Fig. 4*a*, which is typical of that given by a well quenched high-carbon steel, although at 720° C. the austenite would not be far from eutectoid composition. In the specimens quenched from 325° C., the same kind of martensite again appeared, but some of the grains now contained a few small white angular particles. More of them occurred in the specimens quenched from 305° C. They are to be seen in four of the grains shown in Fig. 12*f*, which was taken from the 1200° C. specimen. As the quenching temperature was further lowered, these particles continued to increase in size and quantity until, in the specimens quenched from 250° C., many of the smaller grains consisted entirely of this constituent. Several which were present in the 1430° C. specimen are shown in Fig. 12*g*. Even after a prolonged etching only a faint structure could be detected in these grains, and, as they were relatively soft, the constituent was considered to be austenite. Other grains in the 250° C. specimens were wholly martensitic, and in the remainder the amount of austenite varied between the two extremes. It should be remarked that, under a magnification of about 1500 dia., the constituent which has been described as tempered martensite seemed, in many of the grains incompletely transformed below 300° C., to resemble lower bainite, as illustrated by Vilella and reproduced by Mehl.[1]

While the above interpretation of the structures obtained in these isothermal tests may be open to question, the results, nevertheless, appeared to indicate that the **S**-curve below the knee was not appreciably shifted when the steel was slowly cooled from a very high temperature, since in no instance did the amount of the white constituent regarded as austenite differ much in the two specimens.

Acknowledgments

The author wishes to express his indebtedness to the Metallurgical Department of the National Physical Laboratory for the sample of pure iron, and to Mr. P. Walker, Chief Chemist of the Cargo Fleet Iron Co., for one of the ingot samples.

References

1. R. F. MEHL : *Journal of The Iron and Steel Institute*. 1948, vol. 159, p. 113.
2. W. BETTERIDGE and R. S. SHARPE : *Journal of The Iron and Steel Institute*, 1948, vol. 158, p. 185.

HISTORICAL NOTE NO. 19

An Early Attempt at Trade-Unionism by Ironworkers in North Derbyshire, in 1814

By Dr. H. R. Schubert

THE manufacture of agricultural implements, particularly scythes and sickles, was a flourishing trade in North Derbyshire during the eighteenth century. In 1789, in the parish of Norton, South of Sheffield, 161 workmen were engaged in their manufacture.[1]

The French Revolution in 1789, and the war with the new French Republic in 1793, in which England

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became involved for more than 20 years, caused increased taxation, and constantly rising prices brought suffering to all classes, particularly the working classes. The result was deepening distress and a growing unrest among the workers who, in many places, combined to press their claims for higher wages.

Under the shadow of the French Revolution such associations were regarded with the greatest suspicion and alarm. Two Acts passed in 1799 and 1800 prohibited all combinations, both of employers and employees, and contravention was penalized by imprisonment. The law, however, was not carried out impartially. There was, for example, no prosecution of the master cutlers who, in 1814, formed the Sheffield Manufacturing Union, but any combination of workers was regarded as a political crime.[2]

In such unfavourable circumstances, an attempted combination made by the scythesmiths and journeymen of Norton in 1814, was doomed to failure. A meeting was held and a statement of claims was drawn up and sent to the masters, but this only resulted in a summons to the magistrate's court where nine journeymen were convicted and imprisoned.

Public opinion, although generally agreeing with the employers, was not quite so compassionless to the unfortunate sufferers as Francis Place, an enthusiastic social reformer and once himself a journeyman, would have us believe.[3] Thomas Asline Ward, chronicler of the Norton district, and his fiancée Miss Ann Lewin, sympathized greatly with the Norton scythesmiths, as is shown by an entry in Ward's diary on 23rd May, 1814 : " I cannot help pitying the poor men who are to be punished for combination, one of whom is George Richardson, of Norton, a man who works like a slave for the decent maintenance of his family. It is a shameful thing, they have no other means of raising their wages, and that the only one is punishable."[4]

An anonymous contemporary poem[5] shows that sympathy with the Norton scysthesmiths was not limited to a few individuals, and it also shows that, despite the failure of this early attempt at trade-unionism, the gaoled men were not without a sense of humour.

THE NORTON SCYTHESMITHS' SONG

At the Bowling Green the Meeting was held,
We Journeymen Scythesmiths there did attend :
We drew up a statement as all had agreed
And sent to our Masters, but did not succeed.

We were summoned the Magistrate's Court to attend :
Justice Webb and Sir William nine of us did send
(Because we'd no money nor friend to give bail)
For a fortnight free lodgings in Derby jail.

And when we got there some drinking, some smoking,
While others looked sad,
We thought it was Bedlam and all going mad.

Hard boards and long straw we had for our Beds,
We pulled off our Breeches to put under our Heads,
We pulled off our Coats for both Blanket and Sheet,
We pulled off our Waistcoats to wrap our cold feet.

[1] J. Pilkington, " A view of the Present State of Derbyshire," vol. II, p. 52, Derby, 1789.
[2] S. and B. Webb, " The History of Trade-Unionism," p. 73, London, 1920.
[3] S. and B. Webb, loc. cit, p. 74.
[4] Peeps into the Past. Being Passages from a Diary of Thomas Asline Ward. Edited by A. B. Bell, p. 218, London, 1909.
[5] Printed by H. Armatage, Chantrey Land, p. 350, London, 1910.

HISTORICAL NOTE NO. 20

The Earliest Use of British Cast Iron in Machine Construction

By Dr. H. R. Schubert

At the end of the sixteenth century " we have clear evidence that hammer hursts were being made of cast iron," which is regarded as " perhaps the earliest example of the use of cast iron in machine construction."[1]

The " forge books " of Robertsbridge in Sussex supply evidence which is almost half a century earlier. On the 3rd of May 1554 a payment of 20*d.* was made " for II new horste that were caste at Darvolde ffornes." An entry of the same year but undated, refers to a payment to " Mr. Wecke of Battell for III new horste of hym had at Darvolde ffornes for my M(aste)r('s) fforge at Robarttebrydge at II^{s} VIII^{d} the pece."[2] In the second entry the price of each hammer hurst cast at Darfold furnace is specified, whereas the 20*d.* mentioned in the first entry evidently refers to expenses for carrying two of these hursts to the forge at Robertsbridge to be used there. The furnace at Darfold was situated in the parish of Etchingham in Sussex.[3]

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Dr. Schubert is Historical Investigator to The Iron and Steel Institute.

[1] Rhys Jenkins, " Ironfounding in England 1490–1603," *Transactions of the Newcomen Society*, 1940, vol. XIX, p. 39.

[2] Documents of Lord de l'Isle and Dudley at Penshurst Place (Kent) No. 381. The author is greatly indebted to Lord de l'Isle and Dudley for permission to study these valuable documents, which will be fully dealt with in the " History of the British Iron and Steel Industry " which the author is writing for the Institute.
[3] E. Straker, " Wealden Iron," p. 297 ; 1931, London ; the earliest evidence of this furnace supplied by Straker is dated 1574.

ANDREW CARNEGIE RESEARCH REPORT

The Influence of Low Percentages of Certain Elements on the Microstructure of Pure Iron–Carbon Alloys and Cast Irons

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SYNOPSIS

The influence of small percentages of sulphur, oxygen, silicon, and manganese on the microstructure of pure iron–carbon alloys has been studied. The results prompted further experiments on the influence of aluminium and oxygen additions to cast iron. Aluminium additions modified the form of the manganese sulphide inclusions in cast irons and pure iron–carbon–manganese–sulphur alloys; vacuum melting and inoculation with ferro-silicon producing a similar effect. The diminishing effect of inoculation with respect to time was found to be related to a change in the form of the manganese sulphide inclusions. Superheating influenced the form of the manganese sulphide inclusions and the chilling properties of cast iron.

Experiments on the synthetic production of cast iron from pure materials are described, and further experiments were made to determine the influence of sulphur additions to pure iron–carbon–silicon alloys.

It is concluded that: (i) sulphur and oxygen have similar effects on the mechanism of solidification of pure iron–carbon alloys; (ii) the effects of inoculation and superheating are probably caused by oxygen; and (iii) oxygen in cast irons influences the form of the manganese sulphide inclusions.

Introduction

THE results of recent researches into cast iron metallurgy continually emphasize the significant influence of low percentages of certain alloying elements on the mechanism of solidification of cast irons. Normally these small amounts would lie outside the range of routine chemical analysis methods, and the results have usually been obtained by deliberate additions.

Recent work[1,2,3] has demonstrated that small percentages of cerium and magnesium in cast iron produce pronounced changes in the mechanism of solidification and the resulting microstructures, which are further reflected in the mechanical properties of the irons. Small additions of bismuth and, in particular, tellurium to grey cast irons will cause them to solidify white. Norbury and Morgan[4] have reported the changes in structure produced by passing carbon dioxide through melts containing titanium, and the further changes which occur if this treatment is followed by passing hydrogen through the melt.

Apart from 'heredity' and the numerous anomalies encountered in the production of pig and cast iron, there are two distinct phenomena which seem to be peculiar to cast iron, *viz.*, inoculation and superheating. The effects of inoculation and superheating appear to be independent of changes in chemical composition as determined by present-day methods. Inoculation of cast iron by late additions to the molten metal produces a graphitizing effect which does not exist if the graphitizing element is included in the charge. This inoculating effect diminishes and eventually disappears if the metal is held for a sufficient length of time after treatment.

Superheating has the opposite effect to inoculation, for it increases the chilling tendencies of the iron. The changes in structure are governed by the time and temperature of superheating, but comparatively few data are available, although the effects of superheating are very pronounced.

Cast iron which is being superheated or held after inoculation, is in contact with the refractory material of the container, and also with the surrounding atmosphere, either directly, or indirectly, through a slag cover. Schneble and Chipman[5] reported that the effects of superheating were not observed when melting and casting were conducted *in vacuo*. Their results indicate that the effects of superheating are governed by the surrounding atmosphere, and in particular by carbon monoxide.

The presence of gases in cast iron is generally recognized, but their estimation is a difficult task, and it is a matter for conjecture whether the results obtained from a solidified sample of the iron would give a satisfactory indication of the conditions existing at the time of solidification, for example, the distribution of the oxygen in the liquid iron.

The fundamental researches of Boyles[6,7,8] have revealed the extensive influence of hydrogen, sulphur, and manganese on the mechanism of solidification of pure iron–carbon–silicon alloys. Boyles, and Hanson,[9] appear to be the only investigators who have approached the problems associated with the solidification of cast iron by studying the influence of alloying elements on base alloys prepared from high-purity materials, thus eliminating as many variable factors as possible. Since certain alloying

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elements, when present in very small percentages, produce an appreciable influence on the solidification of cast iron, and as the phenomena of inoculation and superheating appear to be independent of changes in chemical composition as determined by current methods, a study of pure materials would seem to be one of the soundest methods of approaching these problems. If very small percentages, which cannot be estimated chemically, are to be studied, they may be introduced in known quantities by the addition of a base alloy containing an amount sufficiently large to be determined by chemical analysis.

The work was originally planned on these lines, although certain experimental difficulties led to modifications, and some of the results prompted experiments on commercial cast irons.

It was decided initially to study the influence of small percentages of sulphur, silicon, manganese, and aluminium on the solidification of a hypo-eutectic iron–carbon base alloy prepared from pure components. This would eliminate as many indeterminate factors as possible, and allow a study of the influence of the alloying elements, added either singly or in pairs.

The hypo-eutectic pure iron–carbon melts were expected to solidify grey if cooled slowly, and white if cooled rapidly. Whereas it is of interest to find the influence of alloying elements on the form and size of the graphite phase under a fixed but slow rate of cooling, or on the carbide phase under a fixed but more rapid rate of cooling, a more distinctive micrographic indication results if the structure can be changed from one form to the other at a fixed cooling rate. A slight graphitizing, or a carbide stabilizing effect of one of the elements would become more apparent if the melt were cooled at such a rate that it would be just completely white in the untreated condition, thus demonstrating the graphitizing properties of the element: or just completely grey, thus demonstrating its carbide stabilizing properties. Such cooling rates would correspond, in some degree, to the cooling rates at either extremity of the mottled region in a grey iron cast against a chill, provided that the structure changes from a clear chill at the face *via* a mottled zone to a grey zone.

Although the original plan was to conduct all the melts *in vacuo*, it was soon apparent, as a result of the trial melts, that the cooling rate of the graphite spiral type of furnace available was not sufficiently rapid to produce white iron structures in the pure hypo-eutectic iron–carbon alloy. Consequently, most of the melts were prepared in a vertical-tube resistance furnace wound with platinum–rhodium wire. The melts were, therefore, always exposed to the atmosphere or to an atmosphere bounded by a closed graphite crucible, which was fortunate, for otherwise some of the results, which are reported later, would not have been observed.

To minimize heterogeneous structures caused by temperature gradients, the specimens were as small as possible and the weight of each ingot was fixed at 10 g.

The melts were prepared and allowed to solidify in conical fused pure alumina crucibles, 44 mm. high, 18 mm. dia. at the top, 12 mm. dia. at the bottom, and with a wall thickness of 1·5 mm.

EXPERIMENTAL PROCEDURE

Preparation of Base Alloys

An iron–carbon base alloy was prepared in an alumina crucible, using pure iron and electrode graphite. When melting was complete and the melt was quiescent at a temperature of 1430° C., the crucible was removed from the furnace and the melt allowed to air-cool until completely solid. It was then quenched in water and crushed to pieces of 8–22 B.S.S. mesh size. Re-melting this crushed material under atmospheric conditions inevitably causes a certain amount of oxidation of the surfaces of the charge. The fines passing through the 22 B.S.S. sieve were not, therefore, used for the experimental melts, owing to the danger of excessive oxidation per unit mass.

Other base melts were prepared in a similar manner. To them were added sulphur, silicon, and manganese. The total carbon (TC) content and the sulphur, silicon, and manganese contents of the melts were as follows :

Iron–carbon base alloy	TC 3·54%		
Sulphur base alloy	TC 3·51%	S	0·29%
Manganese base alloy	TC 4·09%	Mn	2·97%
Silicon base alloy	TC 3·01%	Si	5·53%

Purity of the Base Alloys

As the following experimental work is based mainly on the study of pure alloys, some qualification of the term 'pure,' as used in this context, may be desirable. As absolute purity is unattainable, certain allowances have to be made. The iron used was obtained in the form of 5-mm. dia. rods, and supplied as being spectrographically pure. The iron, produced by the Westinghouse Electric International Company of America, is called "Puron." The elements Ni, Mn, Ge, Cu, Si, Ag, Ca, and Al are reported as being present in traces as determined by the spectrographic method. Chemical analysis methods gave 0·0075% of Ni and 0·0002% of Cu. The elements B, Co, Cr, Li, Mg, Mo, Na, Pb, Sn, Ti, V, Zn, and Zr could not be detected spectrographically.

Micro-examination of the iron rods, however, revealed the presence of an appreciable amount of dove-grey inclusions, which, since other metallic elements were absent, were assumed to be oxide(s) of iron. These inclusions were entirely absent in the iron–carbon base alloy.

No satisfactory method was available for the estimation of very low percentages of sulphur. The evolution method employed did not discriminate between sulphur contents below the order of 0·008% in the melts to which deliberate lower additions of sulphur had been made. The producers of the iron have suggested a sulphur content as low as 0·00013% in some batches. It will be seen from the following experimental work that this low figure is probably correct. As a result of adding increasing amounts of sulphur (0·0001% upwards) to pure iron–carbon melts prepared from this material, a progressive change in structure commences with the 0·0005% sulphur addition. As the effect is progressive over about 15 melts, it is doubtful if these effects would have been so well defined if the base melt had contained 0·002–0·008% of sulphur.

The iron–carbon base alloy was prepared under atmospheric conditions, with the result that an oxide film formed on the rods. This oxide, and also the oxide present in the iron, gave rise to a considerable boil during melting. It was thought that this evolution of carbon monoxide would displace other gases which might be present, particularly hydrogen.

The electrode graphite used for the preparation of the iron–carbon alloys had a total ash content of 0·049%. The ash had the following composition: SiO_2, 0·017%; Fe_2O_3, 0·011%; Al_2O_3, 0·007%; and CaO, 0·014%.

The silicon and manganese added to the molten iron–carbon alloys for the production of base alloys were purchased as being 'specpure.' Spectrographic analysis of the silicon gave the elements Fe, Cu, Ag, B, Mg, Sn, and Ca as present in traces, and the other metals were not detected. Similarly, the manganese contained traces of Mg, Na, Ca, Cu, and Si, and the other metals could not be detected. Chemical examination of the manganese failed to detect the presence of any sulphur. The surface of this pure manganese is extremely active chemically, and rapidly becomes covered with a thin film of oxide.

The sulphur base alloy was prepared by adding roll sulphur to the surface of the iron–carbon melt. The purity of this sulphur was assumed to be 97–98%, and any impurites would be correspondingly low in the alloys containing sulphur. The aluminium used in the investigation was purchased as being 99·9% pure.

Each of the base melts was examined spectrographically, and the results invariably confirmed what would be anticipated from the figures given by the suppliers. Micro-examination of the iron–carbon base alloy failed to reveal the presence of of any non-metallic inclusions.

Trial Melts

Preliminary trials were made on 10-g. melts prepared from the iron–carbon base alloy, melted in fused alumina crucibles in a graphite-spiral vacuum fusion furnace, held at 1400° C. for 10 min., and then allowed to furnace-cool. The fastest cooling rate attainable in the furnace was not sufficiently rapid to give a white iron structure. The temperatures were taken by means of an optical pyrometer, and the cooling rate, which was approximately uniform over the range 1400–1100° C., was 40–50° C./min. It was not possible to modify the design of this furnace at the time, and consequently most of the melting was carried out in the platinum-wound vertical tube furnace. The current input was controlled by means of a Variac transformer, which gave accurate regulation of the temperature of the melting zone.

SERIES OF MELTS WITH INCREASING SULPHUR CONTENT

Boyles,[6,7] while investigating the influence of sulphur on the solidification of pure iron–carbon–silicon alloys, melted in nitrogen and *in vacuo*, found that as the sulphur content was increased the fine flake graphite structure, forming in the absence of sulphur, became progressively coarser and then finer. Apart from many other interesting fundamental results, Boyles has shown that the usual flake graphite structure found in commercial grey irons is caused by the presence of sulphur or of sulphur and manganese.

In the present investigation, a series of melts with increasing sulphur content was prepared from pure iron–carbon alloys. The cooling rate was such that the untreated base alloy solidified white. A grey structure was obtained by allowing the 10-g. melts to solidify inside the vertical tube furnace after holding at a temperature of 1400° C. for 10 min., whilst air-cooling gave a white structure. A slower rate of 'air-cooling' was obtained by placing the charged alumina crucible inside a closed graphite crucible. The graphite crucible and contents were heated to 1400° C., held for 10 min. at this temperature, and the unit was then removed from the furnace and allowed to air-cool on an asbestos sheet. Although the larger mass cooled more slowly than the alumina crucible on its own, the resulting ingots were found to be consistently white.

The cooling rate of the hot zone of the furnace with the currrent switched off was approximately 15° C./min. in the 1400–1100° C. temperature range. The rate of cooling of the 10-g. ingot in the alumina crucible in air was roughly 200° C./min.—a figure which was deduced from visual observation of the surface of the melt from the instant of removal from the furnace to the commencement of solidification, which was assumed to be at 1140° C. It was not considered advisable to include silica thermocouple sheaths in the pure melts, and sufficiently fine alumina sheaths were not available. The cooling rate and freezing temperature of these melts are therefore not known. Uniformity of conditions throughout the series was considered to be of greater importance. The method of melting and cooling in the graphite container was thought to be satisfactory, and the following series of melts was prepared:

Melt	Sulphur Added, %	Structure
1	Nil	Figs. 1 and 2
2	0·0001	Fig. 3
3	0·0005	Figs. 4 and 5
4	0·001	
5	0·0015	
6	0·002	
7	0·0025	
8	0·003	
9	0·0035	Fig. 6
10	0·004	
11	0·0045	Fig. 7
12	0·005	
13	0·01	Fig. 8
14	0·025	Fig. 9
15	0·05	Figs. 10 and 11
16	0·10	Figs. 12 and 13
17*	Nil	

* Repeat of No. 1.

Each 10-g. melt was prepared from the pure iron–carbon base melt (TC, 3·54%), the sulphur being included by additions of the pure iron–carbon–sulphur alloy (TC, 3·51%; S, 0·29%). Each charge was placed in a small alumina crucible, which was then placed inside the graphite crucible and covered with a graphite lid. The graphite crucible and its contents was placed in the hot zone of the furnace, which was held at a temperature of 1450° C. When

the temperature reached 1400° C., after the initial drop in temperature, the current was adjusted to maintain the furnace at 1400° C. for 10 min. The graphite crucible was then removed and allowed to cool in air by standing it on an asbestos sheet. The temperature cycle of each melt was recorded on a potentiometric recorder, and final examination showed that the heating cycles were uniform throughout the series of melts. The loss in the weight of the graphite crucible from burning was almost eliminated by the presence of graphite supporting columns in the furnace. The furnace was also sealed during melting.

The resulting ingots were sectioned vertically through the centre for micro-examination. It was found that the change in structure was very gradual in specimens 1–12 and consequently the increments of sulphur were increased in specimens 13–16.

Figures 1–13 show that as the sulphur content increases, there is a gradual change from a fine eutectic structure of carbide and transformed austenite (Figs. 1, 2, and 3) to a fine graphite eutectic plus some inverse chill (Figs. 4 and 5), to coarser flake graphite (Figs. 6, 7, and 8), to finer graphite and mottle (Figs. 9, 10, and 11), and then to a completely white iron (Figs. 12 and 13).

There is a distinct difference in the structure of the white iron eutectic of the untreated alloy (Figs. 1 and 2) and that produced by sulphur (Figs. 12 and 13). The former is fine and ledeburitic in form, but the latter is coarser, and the carbide is massive and angular and not suggestive of a normal eutectic structure. Figure 14 shows the ternary sulphide eutectic in a specimen melted and cooled in the same manner, but which contained 0·29% of sulphur.

Boyles' experiments were conducted on pure iron–carbon–silicon alloys, all of which solidified grey. The foregoing series of experiments shows that sulphur has a similar effect on the graphite structure in pure iron–carbon alloys. Furthermore, it is of interest to note that the white iron formed in the absence of sulphur differs from that produced by the presence of 0·1% of sulphur. The white iron eutectic in the untreated alloy is fine and ledeburitic in form, but the white iron produced by the presence of sulphur consists of massive angular carbide, the eutectic austenite apparently being associated with the primary dendrites.

ALUMINIUM–OXYGEN SERIES OF MELTS

During the preparation of some further hypo-eutectic pure iron–carbon melts, each weighing 300 g., one melt, which was air-cooled, solidified grey, but another identical melt, which was cooled more slowly with the object of producing coarser flake graphite, solidified white. This anomaly was observed on several occasions. On closer investigation the only difference, other than rate of cooling, was found to be the presence in the furnace of graphite supporting columns for some melts, and refractory supporting columns for others. The graphite was deliberately included with the object of reducing oxidation of the iron during melting, and consequent loss of carbon.

In the presence of graphite the melts tended to solidify white, and in the absence of graphite their tendency was to solidify grey, an observation which led to an investigation of the influence of melting conditions on the structure of pure iron–carbon alloys.

The sulphur series of melts had been conducted inside a graphite crucible under what may be regarded as 'reducing conditions,' but as conditions were constant throughout, it may be safely assumed that the changes in structure were caused by the sulphur content, which was the only deliberately varied factor.

The presence of graphite in the furnace was assumed to produce reducing conditions, and the absence of graphite to give oxidizing conditions. It was realized that these 'conditions' were vague and indeterminate, but since pronounced changes in structure appeared to be caused by such conditions, experiments were made to obtain further information.

It was assumed that the effects, mentioned previously, were caused by a difference in the oxygen content of the melts. Furthermore, oxygen is closely related to sulphur in the periodic classification of the elements. The two elements might, therefore, produce similar effects on the solidification of pure iron–carbon alloys.

With this object in mind, 10-g. melts were prepared from the pure iron–carbon base alloy (TC, 3·54%). The base melt had been crushed to 8–22 B.S.S. mesh size, the fines being eliminated to minimize oxidation of the charges during heating and melting. The melts were prepared in the small alumina crucibles.

Melting was carried out in the vertical tube furnace, which was maintained at a temperature of 1400° C. throughout the series. The charged crucible was suspended by a platinum-wire cradle for 12 min. in the hot zone of the furnace. Melting was completed in about 3 min., and the melt was therefore held at 1400° C. for about 9 min. The crucible was gently rotated by turning the suspension wire between the fingers to give a short stirring action when melting was complete. The melts invariably presented a slag-free mirror surface, and were quiescent over the final 5 min. of holding at 1400° C. The holding time and temperature were an arbitrary choice.

The normal furnace cooling rate was too slow to give a white iron structure. More rapid rates of cooling were produced by lifting the crucible upwards to predetermined points in the furnace. As the 2-in. bore furnace tube was wound over a central portion of 10 in. and the total length of the tube was 22 in., there was a temperature gradient from the central zone upwards. The furnace, which was continually maintained at a temperature of 800–900° C., was raised to the working temperature of 1400° C., where it was held for about 3 hr. before commencing the melting and cooling procedure. This allowed the furnace sufficient time to attain a uniform condition. The positions in which the crucibles were held in the cooler zones of the furnace were located on the wire by a series of points of suspension which covered the upper 2¼ in. of the furnace tube at ¾-in. intervals. Preliminary experiments revealed that the critical cooling rate existed in this region under

the prevailing experimental conditions, *i.e.*, pure iron–carbon melts which were cooled in the upper end of this region invariably solidified white, and melts which were cooled in the lower end invariably solidified grey. Trial melts under constant conditions were carried out before and immediately after each series of melts, to check that the appropriate cooling rate was being used. Visual observation of the melts from the time they were lifted into the cooling zone until solidification began, indicated that the more rapid cooling rate was approximately 170° C./min., and the slower cooling rate approximately 120° C./min.

If the iron–carbon melts prepared under these conditions contained a fixed amount of oxygen in equilibrium with the carbon of the melt, and if this amount corresponded roughly to that of the sulphur melt which gave coarse flake graphite in the sulphur series of experiments, then an increase or decrease in the oxygen content of the melt might cause the alloy to solidify white. When the charges are heated in the furnace there is a certain amount of surface oxidation which gives rise to the evolution of gas during melting. Immediately after fusion the surface of the metal appears to be covered with a thin film of slag, but as the metal is heated the film clears to give a mirror metal surface, and the melt then remains quiescent.

To decrease, or possibly eliminate, the oxygen present in the melt under these conditions, small quantities of pure aluminium, ranging from 0·001 g. to 0·01 g., were added immediately before cooling. The aluminium was cut in the form of thin turnings, and one end of the tapering particles was wedged in the open end of a fine-bore silica tube (0·5-mm. bore and 0·25-mm. wall thickness). The end was dipped into the molten metal and the aluminium turnings seemed to dissolve instantly, a thin film forming on the surface of the metal immediately after each aluminium addition. The crucible was then lifted to the predetermined position in the furnace and allowed to cool.

To saturate the melt temporarily with oxygen, approximately 1 g. of powdered iron oxide (Fe_3O_4) was added to the surface of the metal, and the melt was allowed to stand for about 15 sec. in the hot zone of the furnace before cooling. The addition of the iron oxide powder caused effervescence, a considerable amount of the oxide powder being thrown out of the crucible. The time interval between the addition of the oxide and the time of solidification was too short to allow any appreciable loss of carbon from the melt. Details of the melts are as follows :

Melt	Treatment	Aluminium Content	Structure
1	Untreated	...	Fig. 15
2	0·01% Al	Not detected	Fig. 18
3	0·05% Al	One spot 0·015% Al Other spot 0·1% Al	Figs. 16 and 17
4	0·1% Al	One spot 0·01% Al Other spot 0·02% Al	Figs. 18 and 19
5	10% Fe_3O_4	...	Fig. 20
6	20% Fe_3O_4	...	Figs. 21, 22, and 23

The structure of the air-melted alloy is shown in Fig. 15. The addition of iron oxide causes the pure iron–carbon melt to solidify white, as shown in Figs. 20, 21, and 22. Although the method of adding the oxygen by means of the powdered oxide is not very satisfactory, the results were consistent. Gas holes are visible in the specimen treated with 20% of Fe_3O_4 (*see* Fig. 23).

The results obtained by the addition of aluminium were not always reproducible. Although most of the specimens treated with 0·01–0·1% of aluminium were completely white, some were mottled and some were grey. The amounts of aluminium being added to the 10-g. melts were very small and the method of addition not entirely satisfactory. It is possible that some of the aluminium could be forced into the silica tube during addition, owing to the ferrostatic head of metal. Spectrographic analysis of the aluminium shows that the distribution was heterogeneous (*see* details of melts). This indicates that the aluminium was not completely in solid solution throughout the melt. Such segregation would be anticipated if most of the aluminium combined with the oxygen present in the melt. (It is interesting to remember this observation when considering the nuclei theory as applied to the solidification of cast iron, for this is an instance of a metal considered to be a potent graphitizer in cast iron causing a grey iron structure in pure iron–carbon alloys to revert to a white iron, while conceivably producing a ' cloud ' of sub-microscopic nuclei at the same time.)

In the present series of experiments, it is reasonable to assume that the addition of aluminium to pure iron–carbon melts under atmospheric conditions influences the distribution of the oxygen which is present, and that the addition of iron oxide to the surface of the melt increases the amount of oxygen, or may temporarily supersaturate the melt. The presence of gas holes in the specimen treated with 20% of iron oxide powder confirms this (*see* Fig. 23).

There is a remarkable similarity between the effect of oxygen and the effect of sulphur on iron–carbon melts made in air and solidifying grey if it is assumed that : (*a*) the melts contain a certain amount of oxygen ; (*b*) the late addition of aluminium deoxidizes the melt, causing it to solidify white ; and (*c*) the addition of iron oxide temporarily supersaturates the melt with oxygen, also causing it to solidify white.

From a study of the micrographs it will be observed that the eutectic carbide produced in the absence of sulphur (Figs. 1 and 2) and by an addition of aluminium in the air-melted specimens (Figs. 16 and 17), has a fine ledeburitic structure. The carbide phase in the specimens which solidify white, owing to a high addition of sulphur or iron oxide, has in both cases a massive angular structure (*cf.* Figs. 12 and 13 with Figs. 21 and 22).

The white iron structure produced by an addition of 10% of iron oxide is of the ledeburitic type, but it will be observed that the primary dendrites (Fig. 20) tend to be less elongated than the dendrites in the white iron produced by an addition of aluminium (Fig. 16). This difference becomes more pronounced in the specimen treated with 20% of iron oxide, and in which the carbide phase is massive and angular (Figs. 21 and 22). This characteristic of the carbide

phase is not so well developed in the oxygen series of melts as in the sulphur series, but the same tendency exists.

SERIES OF MELTS WITH INCREASING SILICON CONTENT

A series of melts containing increasing amounts of silicon was prepared by including in each charge a calculated amount of the pure iron–carbon–silicon alloy (TC, 3·01% ; Si, 5·53%). As the carbon content of the silicon alloy was slightly lower than that of the base alloy there was a slight lowering of the carbon content as the silicon was increased.

With the results obtained by the addition of aluminium in the previous series of experiments as a basis, the melts were cooled at a rate such that the pure iron–carbon melt solidified grey. As silicon is a less effective deoxidizing agent than aluminium, this rate of cooling was increased slightly to accentuate any possible carbide stabilizing effects produced by the silicon acting as a deoxidizer. The details of the melts are as follows :

Melt	Silicon Added, %	Structure
1	...	...
2	0·01	Fig. 24
3	0·03	Fig. 25
4	0·05	Figs. 26 and 27
5	0·10	Fig. 28
6	0·20	Fig. 29
7	0·30	Fig. 30

The micrographs show that increasing the silicon content to 0·05% refines the graphite slightly (Figs. 24–26), with a small amount of eutectic carbide (Fig. 27) appearing in the specimen containing this amount of silicon. Further increases in silicon produce a slight but progressive coarsening of the graphite (Figs. 28, 29, and 30).

SERIES OF MELTS WITH INCREASING MANGANESE CONTENT

Manganese, when present in excess of the amount necessary to neutralize sulphur, is a carbide-stabilizing element in cast iron, but this series of experiments was planned to find whether the deoxidizing properties of small percentages would produce results similar to those obtained by additions of aluminium to pure iron–carbon alloys. The manganese was added by including the calculated amount of the pure iron–carbon–manganese base alloy (TC, 4·09%; Mn, 2·97%) in the charge. The following are details of the melts and the resulting microstructures :

Melt	Manganese Added, %	Structure
1	...	Undercooled graphite (Fig. 31)
2	0·01	
3	0·08	
4	0·12	
5	0·2	,, ,, (Slightly finer)
6	0·3	Mottled. Massive carbide (Fig. 32)
7	0·5	White. ,, ,, (Fig. 33)

There is no appreciable change in structure with additions of up to 0·12% of manganese, but there is some refinement in the graphite size with 0·2% of manganese, whilst 0·3% of manganese produces a mottled structure which is predominantly white. The addition of 0·5% of manganese produces a completely white structure with the carbide in the massive form, similar to that produced by sulphur and oxygen (*cf.* Fig. 33 with Figs. 12 and 21).

When the untreated pure iron–carbon melts are cooled sufficiently rapidly to cause them to solidify white, the eutectic structure is mainly of the ledeburitic type (as seen in Fig. 1) although there may be a little of the massive type of carbide present. In a further series of melts with increasing manganese contents, the cooling rate was just sufficiently rapid to cause the untreated melt to solidify white. The following additions of manganese were made :

Melt	Manganese Added, %
1	Nil
2	0·01
3	0·02
4	0·05
5	0·07
6	0·1
7	0·15
8	0·2
9	0·25
10	0·3
11	0·4
12	0·5

As the manganese content was increased, the amount of the massive carbide increased, but did not reach completion with 0·5% of manganese, as in the case of sulphur (Fig. 12).

THE ADDITION OF ALUMINIUM AND IRON OXIDE TO SMALL MELTS PREPARED FROM CUPOLA IRON

Following upon the results obtained by the addition of aluminium and iron oxide to pure iron–carbon melts, similar experiments were conducted using a cupola-melted base iron composed of : TC, 2·9% ; Si, 1·37% ; Mn, 0·66% ; S, 0·084% ; and P, 0·29%.

Experimental conditions were the same as in the aluminium–oxygen series of experiments. It was surprising to find that melts of the composition mentioned solidified white when cooled at the same rate as that which caused the pure iron–carbon melts to solidify grey. This led to a series of experiments described later (*see* p. 408).

The rate of cooling was sufficiently slow to ensure that the 10-g. melts of remelted cupola iron solidified grey. Five melts were treated with 0·01%, 0·05%, and 0·1% of aluminium and 10% and 20% of iron oxide (Fe_3O_4 powder) respectively. The addition of the small amounts of aluminium did not cause the iron to solidify white, the general structure apparently remaining the same. The treatment with iron oxide, however, gave a white iron, but spectrographic analysis showed that the silicon content had dropped to 0·79%, which may account for the iron solidifying white.

Closer examination of the specimens revealed a change in the form of the manganese sulphide inclusions, and Figs. 34, 35, and 36 show representative structures, both in size and distribution.

The manganese sulphide inclusions in the untreated iron are mainly of the elongated and relatively coarse type (Fig. 34). The addition of aluminium causes the manganese sulphide to form as fine and compact inclusions (Fig. 35), and the addition of iron oxide produces larger compact inclusions (Fig. 36).

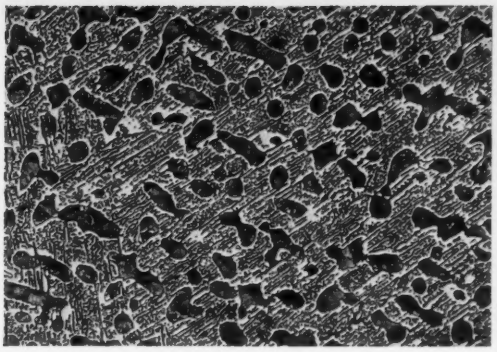


Fig. 1—General structure of pure iron–carbon alloy × 100

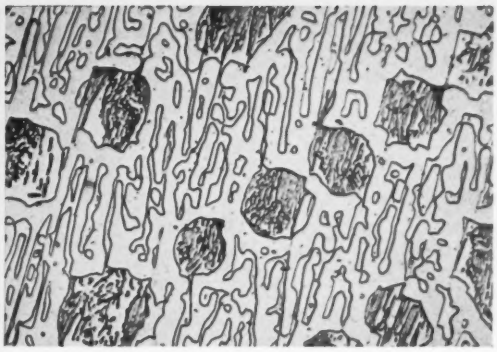


Fig. 2—Structure shown in Fig. 1 × 600

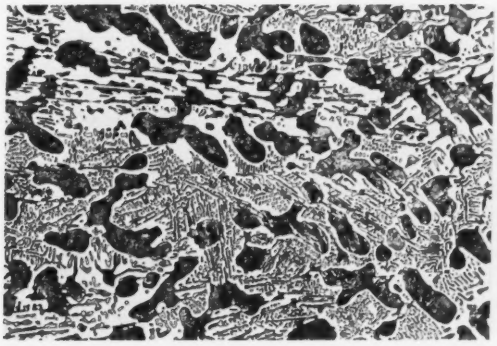


Fig. 3—0·0001% of S × 100

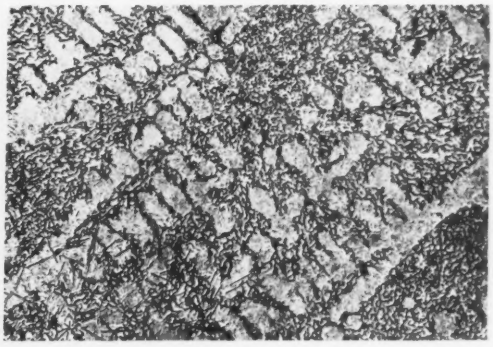


Fig. 4—0·0005% of S × 100

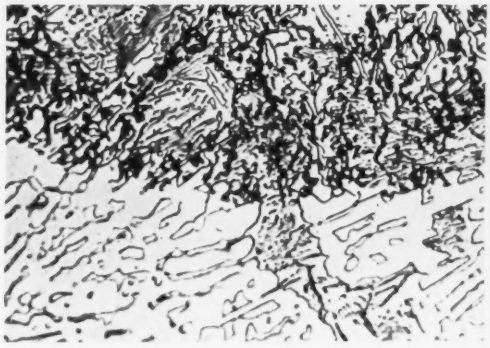


Fig. 5—0·0005% of S × 600

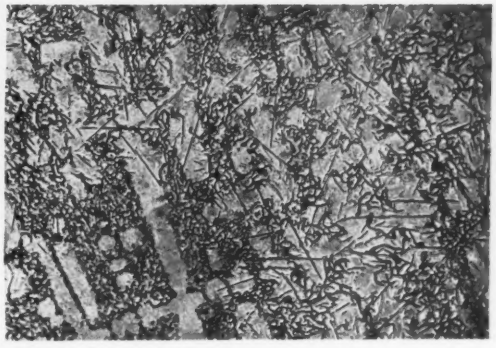


Fig. 6—0·0035% of S × 100

Fig. 7—0·0045% of S × 100

Figs. 3–7—General structure of pure iron-carbon alloys with additions of various percentages of sulphur

Specimens etched in picric acid

Fig. 8—0·01% of S × 100

Fig. 9—0·025% of S × 100

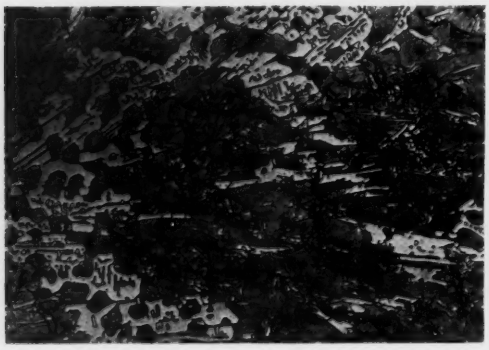


Fig. 10—0·05% of S × 100

Fig. 11—Structure shown in Fig. 10 × 600

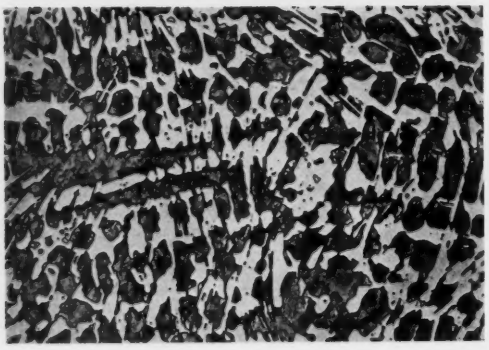


Fig. 12—0·1% of S × 100

Fig. 13—Structure shown in Fig. 12 × 600

Figs. 8–13—General structure of pure iron–carbon alloys with additions of various percentages of sulphur

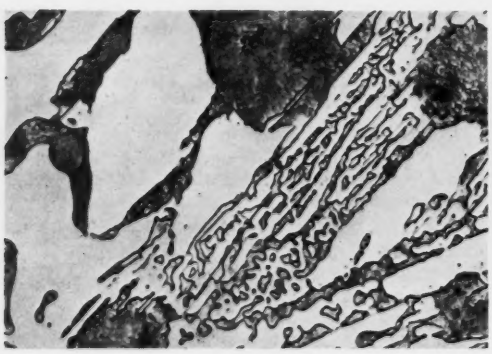


Fig. 14—Ternary eutectic structure in pure iron–carbon alloy with 0·29% of S × 600

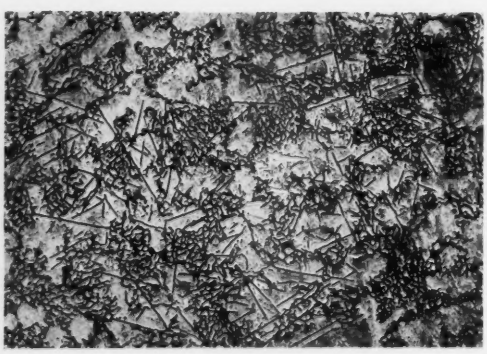


Fig. 15—General structure of pure iron–carbon alloy × 100

Specimens etched in picric acid

Williams]

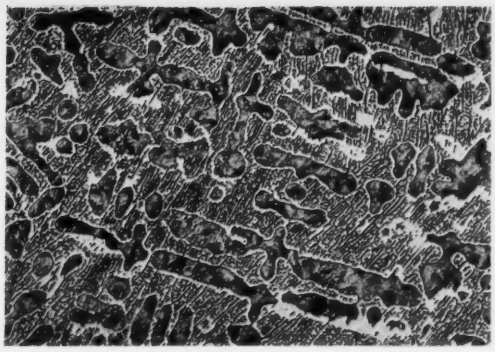


Fig. 16– 0·05% of Al × 100

Fig. 17– Structure shown in Fig. 16 × 600

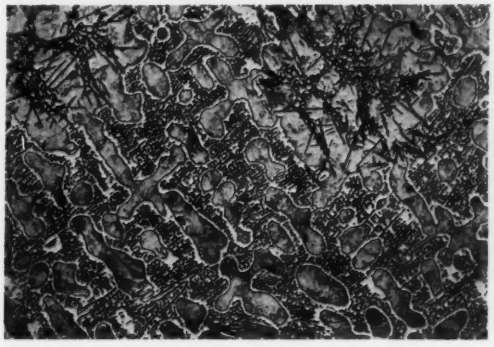


Fig. 18—0·1% of Al × 100

Fig. 19—Structure shown in Fig. 18 × 600

Figs. 16–19—General structure of pure iron–carbon alloys with additions of various percentages of aluminium

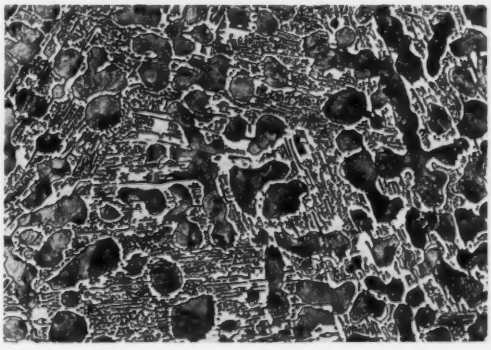


Fig. 20—10% of Fe_3O_4 powder × 100

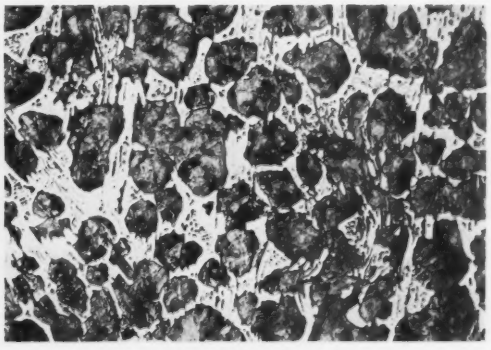


Fig. 21—20% of Fe_3O_4 powder × 100

Fig. 22—Structure shown in Fig. 21 × 600

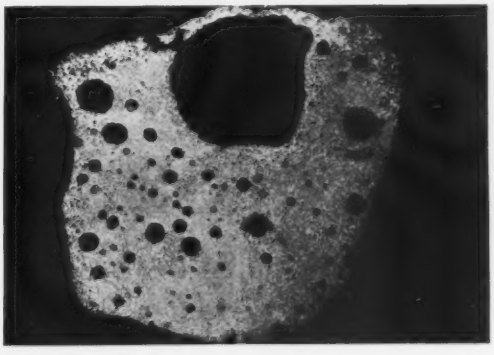


Fig. 23—Macro-section of ingot treated with 20% of Fe_3O_4 powder × 4

Figs. 20–22—General structure of pure iron–carbon alloy treated with Fe_3O_4 powder

Specimens etched in picric acid

[*Williams*

Fig. 24—0·01% of Si × 600

Fig. 25—0·03% of Si × 600

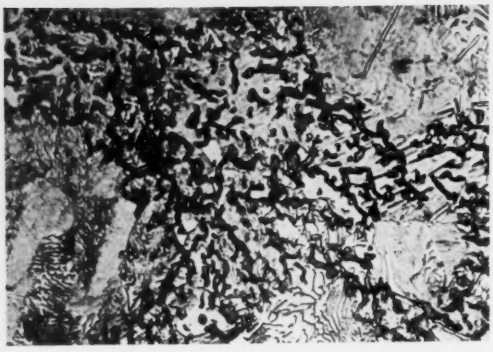


Fig. 26—0·05% of Si × 600

Fig. 27—0·05% of Si, showing carbide × 600

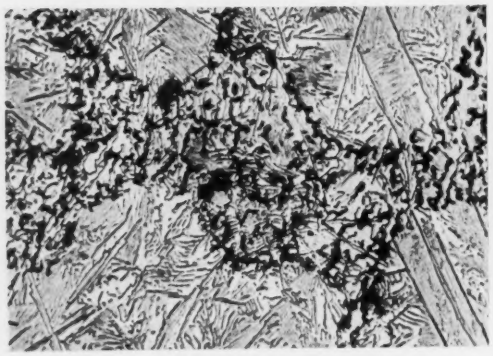


Fig. 28—0·10% of Si × 600

Fig. 29—0·2% of Si × 600

Fig. 30—0·3% of Si × 600

Figs. 24–30—General structure of pure iron–carbon alloys with additions of various percentages of silicon

Specimens etched in picric acid

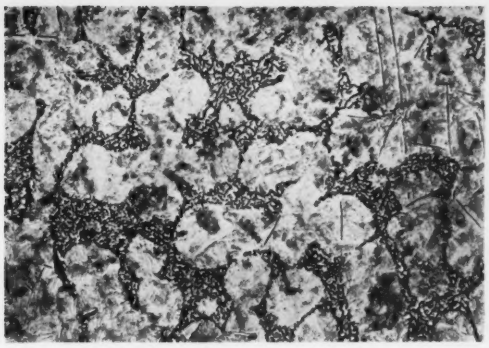


Fig. 31—0·12% of Mn × 100

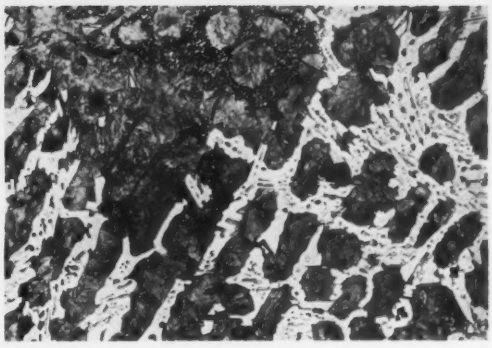


Fig. 32—0·3% of Mn × 100

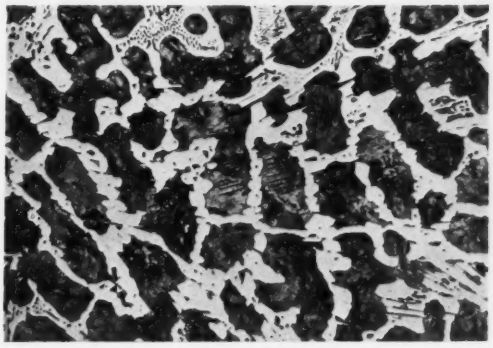


Fig. 33—0·5% of Mn × 100

Figs. 31–33—General structure of pure iron–carbon alloys with additions of various percentages of manganese

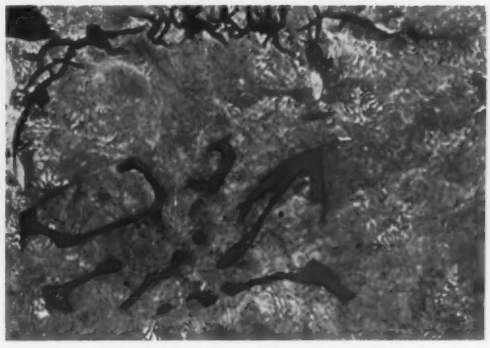


Fig. 34—Elongated or anchor type of manganese sulphide in untreated iron × 600

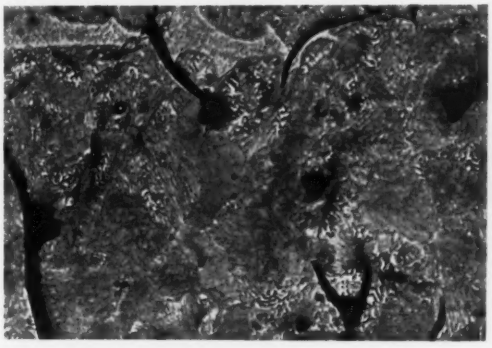


Fig. 35—Compact type of manganese sulphide in iron treated with aluminium (0·01%, 0·05%, or 0·1% of Al) × 600

Fig. 36—Compact type of manganese sulphide in iron treated with 20% of Fe_3O_4 powder × 600

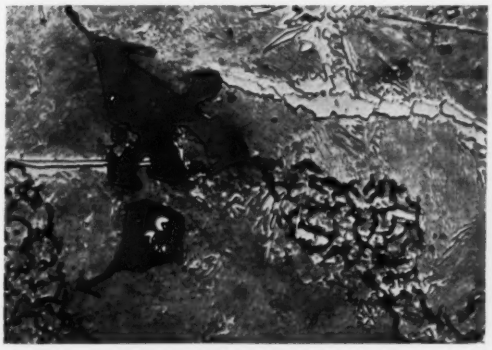


Fig. 37—Manganese sulphide in air-melted pure Fe–C–Mn–S alloy × 600

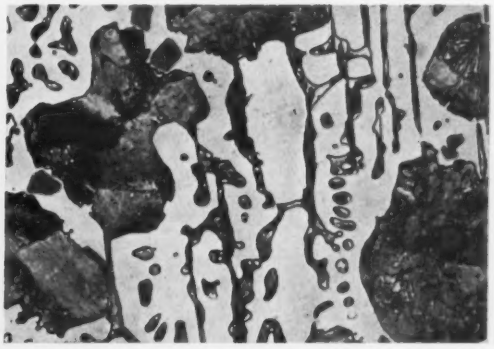


Fig. 38—Manganese sulphide in pure Fe–C–Mn–S alloy treated with 0·1% of Al × 600

Specimens etched in picric acid

[*Williams*

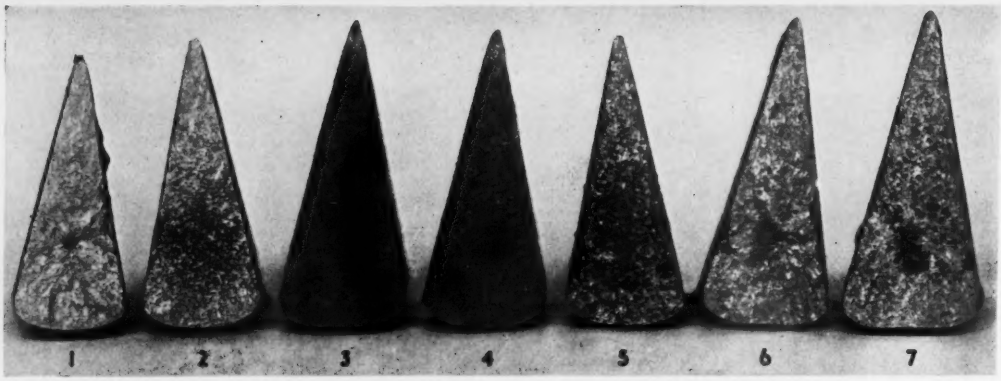


Fig. 39—Chill wedge fractures × 0·8

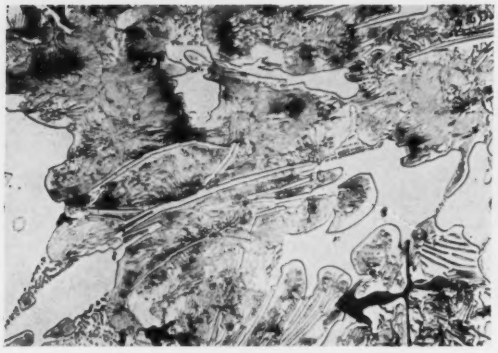


Fig. 40—Elongated or anchor type of manganese sulphide in chill wedge No. 1 (Fig. 39) × 500

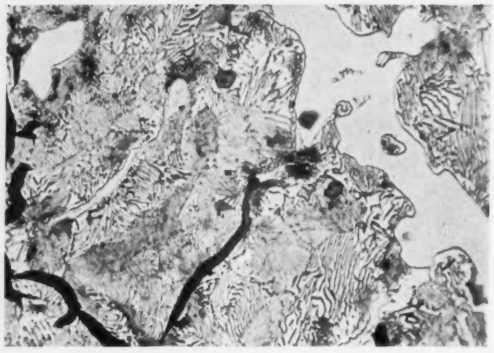


Fig. 41—Compact type of manganese sulphide in chill wedge No. 2 (Fig. 39) × 500

Fig. 42—Compact type of manganese sulphide in chill wedge No. 3 (Fig. 39) × 500

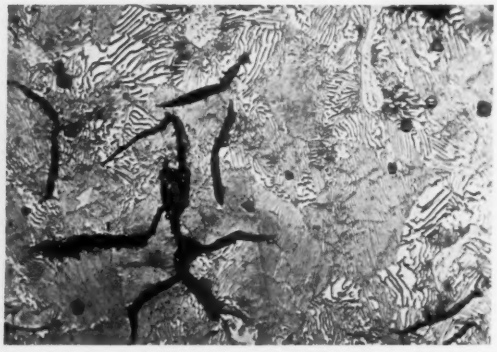


Fig. 43—Compact type of manganese sulphide in chill wedge No. 4 (Fig. 39) ×500

Fig. 44—Compact, but larger, manganese sulphide inclusions in chill wedge No. 5 (Fig. 39) ×500

Fig. 45—Large manganese sulphide inclusions in chill wedge No. 6 (Fig. 39) × 500

Figs. 40–45—Specimens etched in picric acid

Fig. 46—Elongated or anchor type of manganese sulphide inclusion in chill wedge No. 7 (Fig. 39) × 500

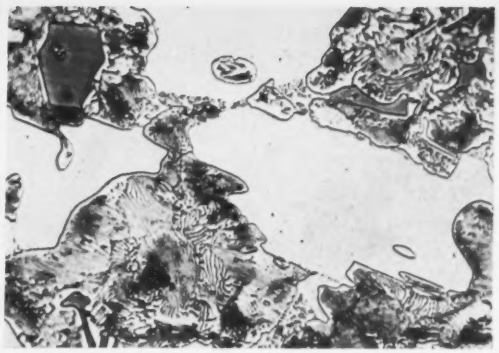


Fig. 47—Large angular and also elongated manganese sulphide in iron superheated to 1350° C. × 600

Fig. 48—Elongated manganese sulphide in iron superheated to 1450° C. × 600

Fig. 49—Compact type of manganese sulphide in iron superheated to 1570° C. × 600

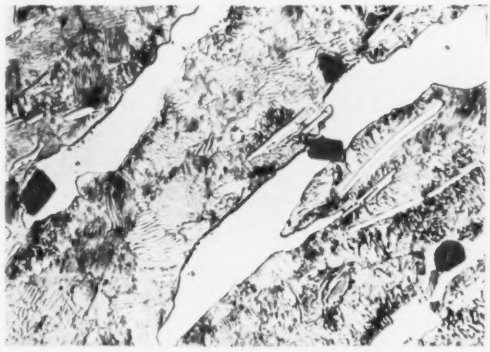


Fig. 50—Compact type of manganese sulphide in iron superheated to 1670° C. × 600

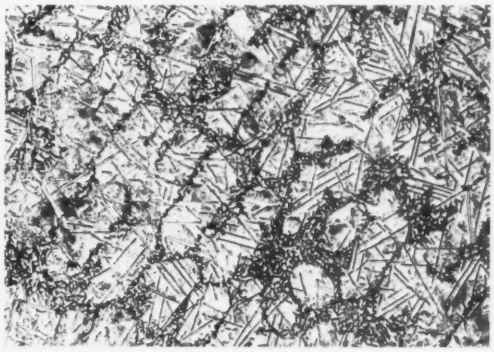


Fig. 51—General structure of pure iron-carbon alloy × 100

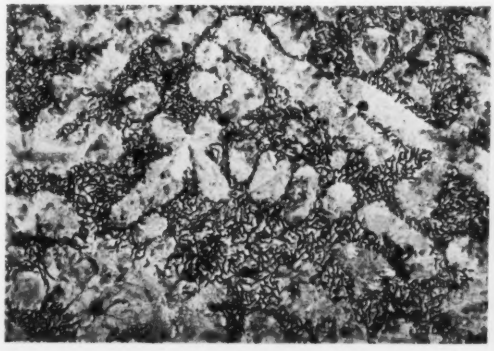


Fig. 52—1·37% of Si × 100

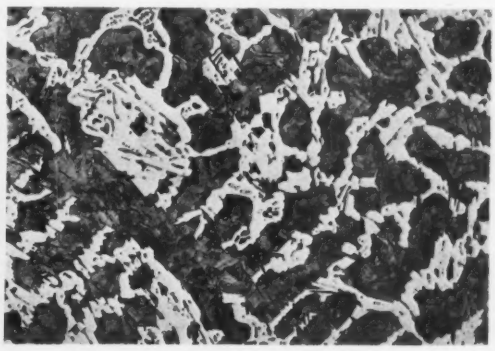


Fig. 53—0·66% of Mn × 100

Figs. 52 and 53—General structure of pure iron-carbon alloy with additions of silicon and manganese

Specimens etched in picric acid

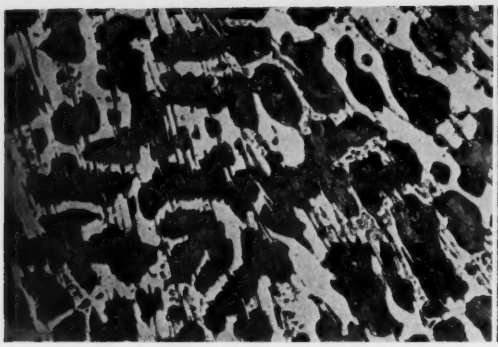


Fig. 54—0·084% of S × 100

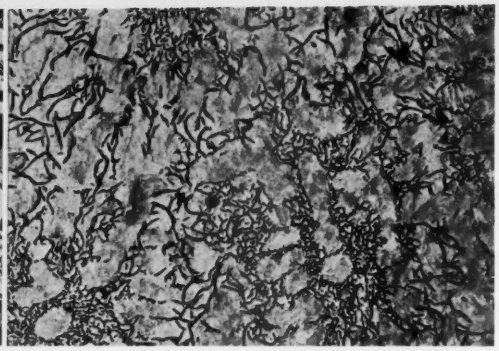


Fig. 55—1·37% of Si and 0·66% of Mn × 100

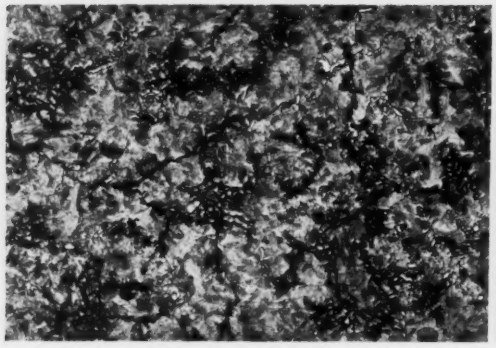


Fig. 56—1·37% of Si and 0·084% of S × 100

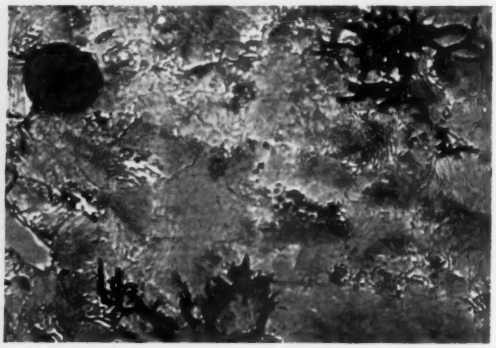


Fig. 57—Part of structure shown in Fig. 56 ×600

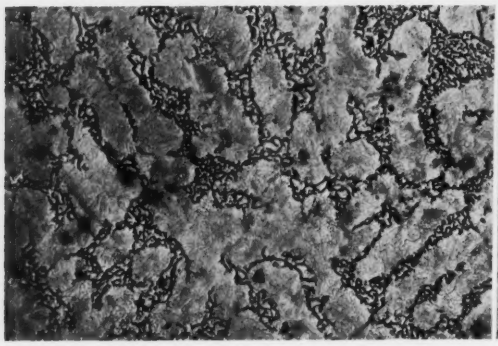


Fig. 58—0·66% of Mn and 0·084% of S ×100

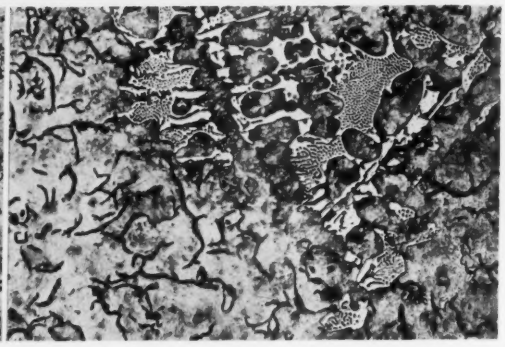


Fig. 59—1·14% of Si, 0·55% of Mn and 0·07% of S × 100

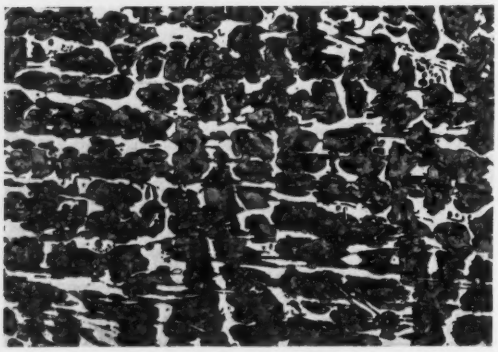


Fig. 60—General structure of remelted cupola iron, TC 2·9%, Si 1·37%, Mn 0·66%, S 0·084%, and P 0·29% × 100

Figs. 54–59—General structure of pure iron–carbon alloy with additions of sulphur and various combinations of silicon, manganese, and sulphur

Specimens etched in picric acid

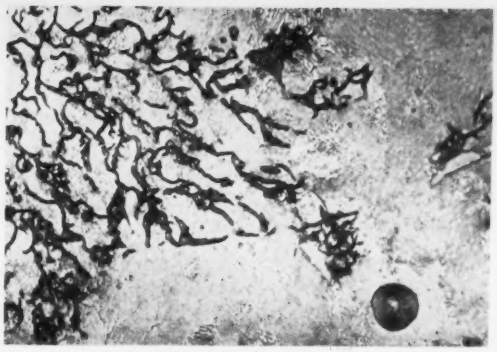


Fig. 61—Nodular and mesh type graphite in Fe–C–Si alloy with 0·35% of S × 600

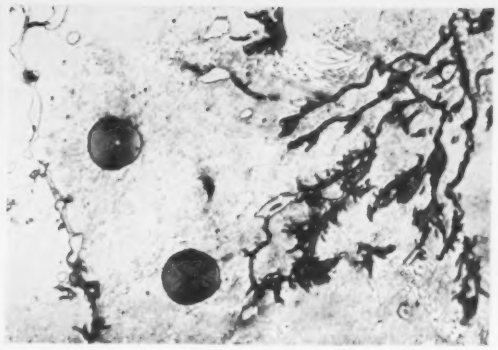


Fig. 62—Another section of alloy shown in Fig. 61 × 600

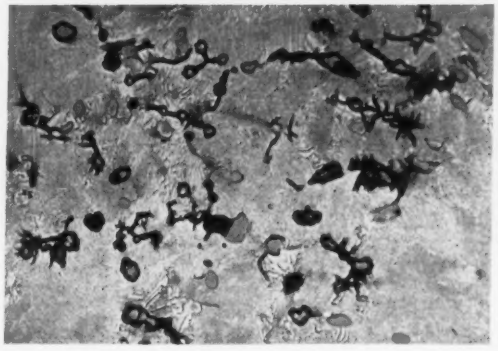


Fig. 63—Sulphide and graphite structures in alloy shown in Fig. 61 × 600

Fig. 64—Graphite film in Fe–C–Si alloy with 1·3% of S × 600

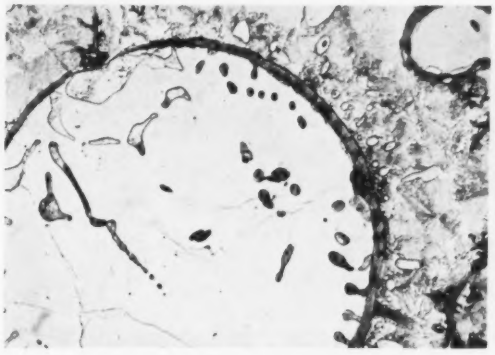
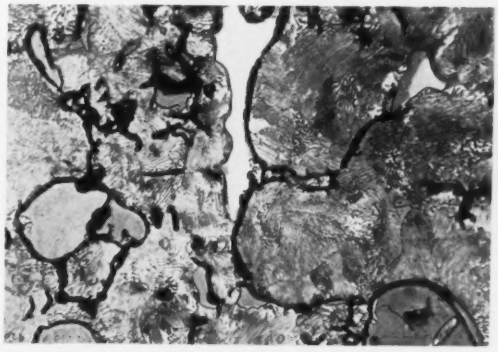


Fig. 65—Globular iron sulphide surrounded by graphite film in alloy shown in Fig. 64 × 400

Fig. 66—Sulphide and carbide surrounded by graphite films in alloy shown in Fig. 64 × 600



Figs. 67 and 68—Sulphide, graphite, and carbide structures in alloy shown in Fig. 64 × 600

Specimens etched in picric acid

[*Williams*

Fig. 69—Graphite and carbide structures in alloy shown in Fig. 64 × 600

Fig. 70—Graphite in alloy shown in Fig. 64 × 600

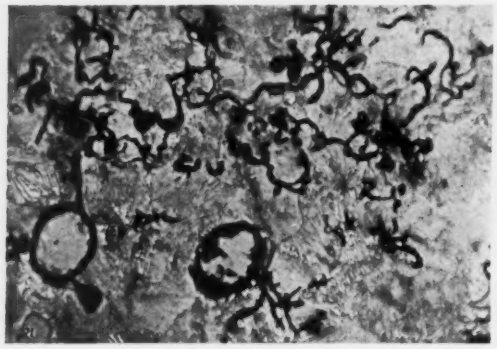


Fig. 71—Sulphide and graphite structures in alloy shown in Fig. 64 × 600

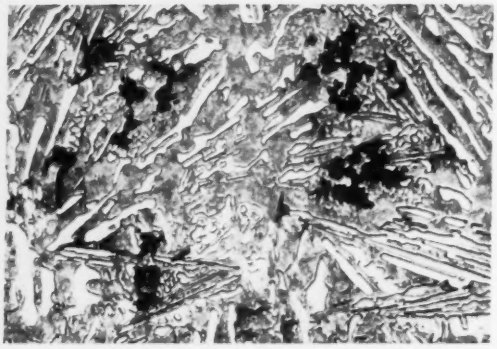


Fig. 72—Carbide and graphite structures at edge of rapidly cooled Fe–C–Si alloy × 600

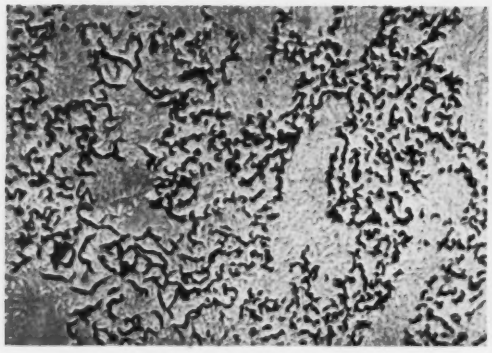


Fig. 73—Graphite structure in centre of rapidly cooled alloy shown in Fig. 72 × 600

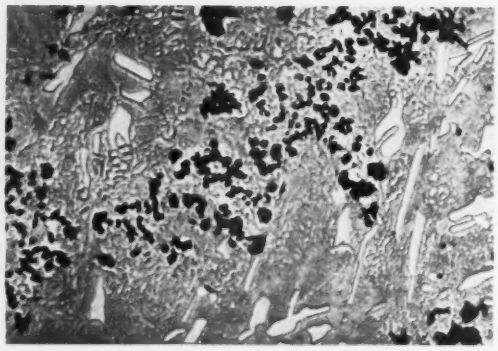


Fig. 74—Carbide and graphite structures in rapidly cooled alloy shown in Fig. 72 × 600

Fig. 75—Graphite film in iron showing defect of 'cold shut' × 100

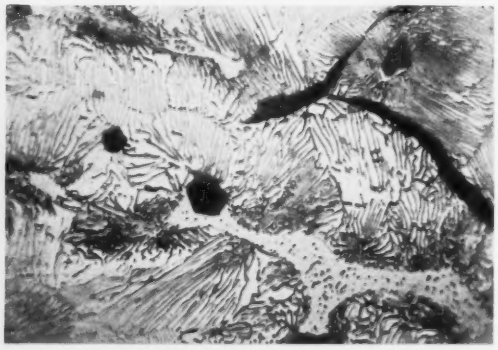


Fig. 76—Duplex sulphide inclusion in iron treated with aluminium × 1250

Specimens etched in picric acid

This series of experiments was repeated using a more rapid rate of cooling (air-cooling). The form and distribution of the manganese sulphide inclusions seemed to be independent of the rate of cooling, but there was a general refinement of size. The air-melted specimens consistently gave the elongated type of manganese sulphide, and the melts treated with aluminium consistently gave the completely compact type, but the addition of iron oxide did not always cause a substantial reversion from the type shown in Fig. 34 to that in Fig. 36.

THE ADDITION OF ALUMINIUM AND IRON OXIDE TO PURE IRON–CARBON–MANGANESE–SULPHUR MELTS

Additions of aluminium and iron oxide (Fe_3O_4) were made to hypo-eutectic melts prepared from the pure base alloys to give the following composition : TC, 3·5% ; Mn, 0·5% ; and S, 0·08%.

The 10-g. melts were heated to 1400° C., held for 10 min. at this temperature, treated with aluminium or iron oxide, and then cooled almost immediately.

The first melt was untreated. The second melt was given a late addition of 0·1% of aluminium and the third was treated with 10% of powdered iron oxide. The typical manganese sulphide inclusions in the untreated and aluminium-treated melts are shown in Figs. 37 and 38 respectively. The melts treated with iron oxide showed the presence of iron sulphide, which indicated the removal of the manganese by oxidation. Treatment with iron oxide was repeated several times, using smaller amounts of the oxide, but with the same result. It may be assumed that the manganese is readily oxidized out of melts in the absence of silicon.

The addition of aluminium caused the melt to solidify white, but the untreated melt solidified grey. The addition of the aluminium thus produced two effects. It caused the manganese sulphide inclusions to form as fine compact inclusions (an effect which was also produced in the remelted cupola-iron series of experiments) and it also caused the iron to solidify white (an effect which was produced in the pure iron–carbon series of experiments).

The manganese sulphide inclusions produced in the untreated, pure Fe–C–Mn–S alloy (Fig. 37) may be classified as elongated or anchor type, although the form is not very pronounced. When this melt was repeated by heating to 1500° C., and held for 10 min., practically all the manganese sulphide was of the anchor or elongated type (*see* Figs. 34, 40, 46, and 48).

INFUENCE OF VACUUM MELTING ON THE FORM OF THE MANGANESE SULPHIDE

It was not known whether the fine angular and regularly distributed form of manganese sulphide produced by the late additions of aluminium was caused directly or indirectly by the aluminium. Assuming that there is some oxygen present in the melt and that it influences the form of the inclusions identified as manganese sulphide, then the influence of the aluminium may be caused by its deoxidizing properties. Aluminium may, however, form a sulphide (Al_2S_3). Experiments were conducted to determine whether the presence of this sulphide would alter the distribution of the sulphur and the composition of the manganese sulphide inclusions.

Four melts were made *in vacuo*, on the assumption that vacuum melting of a cast iron removes the bulk of the gases present, including oxygen. Details of the melts are as follows :

	Composition Sought				
Melt	TC,%	Mn,%	S,%	Al,%	Si,%
1	3·4	0·6	0·1	Nil	Nil
2	3·4	0·6	0·1	0·06	Nil
3	3·4	0·6	0·1	Nil	0·75
4	3·4	0·6	0·1	0·144	0·75

The melts were prepared from pure base alloys, to eliminate as many as possible of the unknown factors. The second melt differed from the first in aluminium content only. Silicon was introduced into the third and fourth melts, the aluminium content of the fourth differing from that of the third. (The differences in aluminium were due to the limited range of base alloy compositions.) The silicon was introduced to see whether it would influence the form of the manganese sulphide in the pure alloys. Air-melting of melts 1 and 3 gave the elongated or anchor type of manganese sulphide inclusion.

The melts, each weighing 10 g., were prepared in alumina crucibles, heated to 1400° C. for 10 min., and furnace-cooled. The vacuum at 1400° C. was 0·03 mm. of mercury. Micro-examination of the specimens showed that the compact type of manganese sulphide had formed in each ingot (*see* Fig. 35). Spectrographic examination did not reveal any aluminium in specimens 1 and 3.

The aluminium in melt 2, the silicon in 3, and the silicon and aluminium in 4 did not affect the form or distribution of the manganese sulphide inclusions. The elongated or anchor type of manganese sulphide was entirely absent in all specimens. It is reasonable to assume from these results that the late addition of aluminium to air-melted iron containing manganese sulphide in the elongated form, has a deoxidizing effect which modifies the form of the inclusions to the fine compact and uniformly distributed type.

THE RELATIONSHIP OF CHILLING TENDENCIES TO TYPE OF MANGANESE SULPHIDE INCLUSIONS IN CAST IRON

The foregoing experiments had revealed some interesting effects produced by additions of small amounts of aluminium and iron oxide, and it was decided to treat larger quantities of iron and to cast chill wedges in an attempt to find some relationship between the chilling tendencies (if altered by the treatment) and the resulting modified form of the manganese sulphide inclusions.

Melts weighing 250 lb. were prepared in an oil-fired crucible (salamander) furnace, from the following basic charges :

110 lb. of low-silicon iron (TC, 4·03% ; Si, 0·66% ; Mn, 0·43% ; S, 0·054%).
90 lb. of low-silicon, high-sulphur iron (TC, 3·49% ; Si, 0·62% ; Mn, 0·33% ; S, 0·264% ; P, 0·056%).
43 lb. of steel scrap
2¼ lb. of 80% ferro-silicon
6 oz. of ferro-manganese
4 lb. of ferro-phosphorus (24% phosphorus).

The following was the approximate composition sought: TC, 2·8%; Si, 1·1%; Mn, 0·44%; S, 0·148%; P, 0·47%.

The whole of the charge was placed in the cold crucible with the ferro-silicon, ferro-manganese, and ferro-phosphorus at the bottom. Melting and heating to a temperature of approximately 1420° C. took 4½ to 5 hr. The metal was then poured into a pre-heated hand shank in five taps of 45 lb. each, or seven taps of 30 lb. each. The additions were either placed in the hand shank just before pouring, or dropped on to the surface of the metal and then mixed in by means of a salamander plunger. A chill wedge and 1·2-in. dia. bar were cast from each tap.

First Oil-Furnace Melt

This was made to determine the effect of additions of aluminium and iron oxide on the form of the manganese sulphide inclusions and on chill formation.

Five taps were made, each of 45 lb. The micro-specimens were taken from the region remote from the apex of the chill wedges. The details of the treatment of each tap and the microstructures are as follows:

Tap	Additions	Form of Manganese Sulphide
1	None	Elongated or anchor (*see* Fig. 40)
2	0·005% Al to metal in ladle	Cuboid, finely distributed (*see* Fig. 41)
3	0·025% Al to metal in ladle	As in tap 2
4	20 g. of Fe_3O_4 powder to metal in ladle and plunged in	As in tap 1
5	50 g. of Fe_3O_4 powder placed in ladle and metal poured on	As in tap 1

All the chill wedges were white, and therefore no information was obtained on the effect of the additions on the chilling properties of the iron. Additions of iron oxide powder did not appear to influence the form of the manganese sulphide, although the inclusions in tap 4 appeared to be more elongated than those in tap 1.

Second Oil-Furnace Melt

This melt was a repeat of the first melt, but with the exception that the ferro-manganese and ferro-silicon additions were made at a temperature of about 1400° C. The object of the late addition of the ferro-alloys was to eliminate, as far as possible, any losses from oxidation. The silicon content of the first melt was lower than the calculated amount, and it was thought that this was partly the cause of the wedges solidifying white.

All the chill wedges from this oil-furnace melt were grey, and micro-examination showed that the manganese sulphide inclusions were of the fine compact type in each wedge.

The only difference between this and the first oil-furnace melt was in the late addition of the ferro-alloys. It was immediately realized that the late addition had produced an inoculating effect, and had resulted in the formation of the compact type of manganese sulphide inclusion. These observations prompted the third oil-furnace melt.

Third Oil-Furnace Melt

The object of the melt was to find the relationship between the form of the manganese sulphide inclusions and the diminishing effect of inoculation on holding the inoculated metal.

The ferro-silicon and ferro-manganese were included in the cold charge to eliminate the effects produced in the previous melt. The silicon content of the charge was increased by 0·2% to reduce the chilling tendencies of the iron.

Seven taps, each of 30 lb., were taken, and the details of the treatments are as follows:

Tap	Treatment
1	Untreated
2	0·01% of Al added to metal in ladle and stirred in with a steel rod
3	0·5% of 80% ferro-silicon added to metal in ladle and plunged in
4	0·5% of 80% ferro-silicon added to metal in furnace crucible and plunged in. Tap 4 was taken as soon as the ferro-silicon had dissolved
5	Taken from furnace 25 min. later, the metal being held meanwhile in the furnace at approximately 1430° C. with crucible lid removed, *i.e.*, the metal surface was exposed to the atmosphere
6	Taken after holding for further 25 min. in furnace
7	Taken after holding for further 25 min. in furnace

The chemical analyses of the chill wedges are given in Table I.

The ferro-silicon used as the inoculant contained 0·74% of aluminium, which is equivalent to an addition of 0·004% of aluminium to the melt.

The fractured faces of the chill wedges are shown in Fig. 39 and are numbered in the order in which they were cast. The types of manganese sulphide inclusions are shown in Figs. 40–46. The micro-specimens were taken from the base of each wedge.

A 10-g. melt was prepared from tap 1 of this melt

Table I

ANALYSIS OF CHILL WEDGES FROM THIRD OIL-FURNACE MELT

Wedge From Tap	TC, %	Si, %	Mn, %	S, %	P, %	Aluminium by Spectrographic Analysis, %	
						Base of Wedge	Apex of Wedge
1	2·78	1·10	0·42	0·134	0·47	Nil	Nil
2		1·12	0·40	0·135		<0·005	<0·005
3		1·50	0·43	0·128		Not detected	Not detected
4		1·56	0·43	0·130		,, ,,	,, ,,
5		1·53	0·41	0·126		,, ,,	,, ,,
6		1·51	0·42	0·126		,, ,,	,, ,,
7		1·55	0·40	0·126		,, ,,	,, ,,

(untreated) and melted in an alumina crucible *in vacuo*. The melt was heated to a temperature of 1400° C., held for 10 min., and then furnace-cooled. The manganese sulphide inclusions were entirely of the compact type (*see* Fig. 41).

A study of the micrographs shows that the manganese sulphide inclusions in the untreated material are of the elongated or anchor type (Fig. 40), and that the chill wedge cast from this material is almost completely white. The addition of 0·01% of aluminium to the ladle changes the manganese sulphide to the compact form shown in Fig. 41 and produces a grey mottle in the centre of the chill wedge. The addition of 0·5% of ferro-silicon to the metal in the ladle also changes the sulphide inclusions to a fine compact form (Fig. 42). The inclusions appear to be finer and more numerous than those produced by an addition of aluminium alone. This addition of ferro-silicon removes all the chill from the wedge (No. 3, Fig. 39). (The amount of aluminium introduced by means of the ferro-silicon was calculated to be approximately 0·004%.) Spectrographic analysis of the two wedges showed a trace of aluminium in the wedge treated with aluminium, but none could be detected in the wedge treated with ferro-silicon. Although the manganese sulphide inclusions in wedges Nos. 2 and 3 are presumably of the same type, the amount of chill is not comparable. It must, of course, be remembered that chemical analysis gave a silicon content of 1·12% in wedge No. 2 (Fig. 39) and 1·50% in wedge No. 3 (Fig. 39). It had been hoped to add pure silicon or aluminium-free ferro-silicon as an inoculant, to determine whether the presence of aluminium or some other powerful deoxidizing element caused the increased chill-removal associated with inoculation with ferro-silicon, but all the silicon alloys available were found to contain aluminium.

The result of holding the metal in the furnace for 75 min. was a gradual elimination of the effects of inoculation, although wedge No. 7 (Fig. 39) contained some grey mottle. This decrease in the effect of inoculation is also reflected in a change in the type of manganese sulphide. Some chill is formed in wedge No. 5 (Fig. 39) after holding for 25 min., and the manganese sulphide inclusions are larger, although of the same type (Fig. 44).

Holding for a futher 25 min. gives a wedge which is almost completely white (No. 6, Fig. 39), and manganese sulphide inclusions of the type shown in Fig. 45. A further 25 min. does not alter the chill wedge appreciably (No. 7, Fig. 39), but the manganese sulphide inclusions have reverted to the original anchor or elongated type (*cf.* Figs. 40 and 46).

Fourth Oil-Furnace Melt

This was made to determine the effect of holding on the chilling properties and the manganese sulphide inclusions in an aluminium-treated melt.

The charge was the same as that for the third oil-furnace melt. The metal was heated to a temperature of 1430° C. (approx.) and held at this temperature with the crucible lid removed throughout the experiment. The details of the treatment and the aluminium content of the seven taps are as follows:

Tap	Treatment	Aluminium by Spectrographic Analysis, % Base	Apex
1	Untreated	<0·005	Not Detected
2	0·015% of Al added to ladle and stirred in	<0·005	<0·005
3	Cast after an addition of 0·015% of Al had been made to metal in the crucible	<0·005	<0·005
4	Cast after a further addition of 0·015% of Al had been made to metal in the crucible	<0·005	<0·005
5	Cast after metal in the crucible had been held for 30 min.	Not detected	<0·005
6	Cast after metal in the crucible had been held for a further 30 min.	Not detected	<0·005
7	Cast after remaining 40–50 lb. of metal in furnace had been treated with 6 g. of hematite ore. The ore was dropped on to surface of metal and allowed to stand for 5 min.	Not detected	Not detected

Chemical analysis of tap 1: TC, 3·88%; Si, 1·07%; Mn, 0·44%; S, 0·148%; and P, 0·47%.

All the chill wedges were white with the exception of Nos. 2, 3, and 4, which showed a little grey mottle (*see* No. 2, Fig. 39).

The type of manganese sulphide in each of the wedges was as follows:

Wedge from Tap	Type of Manganese Sulphide Inclusions
1	Elongated or anchor (*see* Fig. 40)
2	Finely distributed compact (*see* Fig. 41)
3	do. } Becoming larger in size and less numerous
4	do. }
5	do. }
6	do. Some elongated
7	All elongated or anchor, as in tap 1

The hematite ore was added to the metal in the crucible after tap 6 had been taken, as it was not possible to hold the metal for a further 30 min. (It was assumed that the diminishing effect of inoculation and also the accompanying change in the form of the manganese sulphide inclusions was caused by oxidation of the melt.) Spectrographic examination of the wedges showed that traces of aluminium were present in taps 1–6, but aluminium was absent in tap 7.

INFLUENCE OF SUPERHEATING ON CHILL FORMATION AND FORM OF MANGANESE SULPHIDE

The experiments show that there is a relationship between the form in which the manganese sulphide solidifies and the inoculating effects of aluminium and ferro-silicon. It is well known that inoculation reduces the chilling tendencies and that superheating has the opposite effect. A study of the results of some exploratory experiments confirms the complex nature of superheating effects, and therefore the following results are all that are reported at the present stage.

Some untreated bars from the fourth oil-furnace melt were cleaned free of sand and melted in a pure alumina crucible in a high-frequency induction furnace. Each melt weighed 5 lb., and a chill wedge was poured at each superheating temperature. The metal was rapidly heated to the superheating temperature and held for 10 min. before pouring the chill wedge directly from the furnace. The first melt was heated to

1350° C., the second to 1450° C., the third to 1570° C., and the fourth to 1670° C. The temperatures were taken by means of an optical pyrometer and are correct only to within ± 20° C.

The four chill wedges were white, and no information was therefore obtained on the effect of superheating on chill formation. Superheating, however, influenced the form of the manganese sulphide inclusions. The manganese sulphide in the wedge cast from the metal heated to 1350° C. was of the large angular and elongated anchor type shown in Fig. 47. All the manganese sulphide in the wedge poured from the metal at 1450° C. was of the elongated anchor type shown in Fig. 48, and that in the wedges poured from 1570° C. and 1670° C. was of the compact angular type shown in Figs. 49 and 50.

No aluminium was revealed by spectrographic examination of the wedges in the first three melts, but the metal heated to 1670° C. contained a maximum of 0·005%, which was picked up from the crucible by reduction of the alumina by the carbon in the melt at high temperatures. The presence of this small amount of aluminium could account for the compact type of manganese sulphide in this melt, but not for the similar structure obtained in the melt heated to 1570° C. These manganese sulphide inclusions are very similar to the inclusions produced in a melt prepared from the same iron and melted *in vacuo* for 10 min. at a temperature of 1400° C., and then furnace-cooled.

An attempt was made to relate the form of the manganese sulphide inclusions to the changes in chilling properties produced by superheating, and also by superheating followed by holding at lower temperatures, but the changes are very complex and require careful interpretation.

The following general observations have been made in the experiments on superheating. Firstly, the compact type of manganese sulphide inclusions, shown in Figs. 49 and 50, follows from melting at temperatures above 1480–1500° C. Secondly, the elongated anchor type of inclusions, shown in Figs. 40, 46, and 48, is formed after melting in the region of 1400° C., and thirdly, the elongated and the large types of inclusion, shown in Fig. 47, are produced by melting at temperatures in the region of 1300° C. These observations apply to melts of the compositions quoted previously, and which have been melted in an alumina crucible and exposed to atmospheric conditions.

THE SYNTHETIC PRODUCTION OF A CAST IRON FROM PURE MATERIALS

In the series of experiments dealing with the effect of adding small percentages of aluminium to 10-g. melts of remelted cupola iron, it was found that whereas the pure iron–carbon melt solidified grey under the particular cooling rate condition, the remelted cupola iron solidified white, although containing 1·37% of silicon. To find the individual influence of Si, Mn, and S, and the combined influence of Si + Mn, Si + S, Mn + S, and Si + Mn + S, a series of eight melts was prepared from the pure base alloys. Details of the compositions of the eight pure base alloy melts are given in Table II, together with the composition of the remelted cupola iron, which is listed as melt 9.

Each melt was held in the furnace for 12 min. at a temperature of 1400° C. The cooling rate was such that the pure iron–carbon alloy solidified grey, giving the structure shown in Fig. 51.

The addition of 1·37% of silicon alone to the pure base alloy does not produce an appreciable coarsening of the graphite, although the element is generally regarded as a potent graphitizer (*cf.* Fig. 52 with Fig. 51).

The addition of 0·66% of manganese and 0·084% of sulphur individually causes the alloy to solidify white, giving the massive type of carbide, which is more evident in the sulphur alloy (Fig. 54) than in the manganese alloy (Fig. 53). The addition of manganese and sulphur gives undercooled graphite, as shown in Fig. 58. (The manganese sulphide inclusions are comparable with those shown in Fig. 37)

The addition of silicon plus manganese gives a slightly coarser graphite structure (Fig. 55) than that produced by silicon alone (Fig. 52), although the manganese alone is a carbide stabilizer (Fig. 53).

The addition of silicon plus manganese plus sulphur gives the coarsest flake graphite structure, as distinct from the undercooled type of graphite appearing in the other grey specimens, but the specimen was mottled, as shown in Fig. 59. This was the alloy in which the percentages of silicon, manganese, and sulphur were reduced by approximately one-sixth.

The remelted cupola iron solidified white, but the composition differed from that of melt 8, particularly in the carbon and phosphorus content.

Attention was turned to the interesting graphite structures produced in the alloy treated with silicon and sulphur. The general structure of this alloy is shown in Fig. 56, and closer examination revealed the presence of some graphite nodules (Fig. 57).

THE ADDITION OF SULPHUR TO PURE IRON–CARBON–SILICON ALLOYS

The observation of the graphite nodules in the pure iron–carbon–silicon–sulphur alloy led to a further series of melts with varying silicon and sulphur contents. In one series the silicon content was fixed

Table II

COMPOSITION OF MELTS PREPARED FROM PURE BASE ALLOYS

Melt	Composition Sought					Structure
	TC, %	Si, %	Mn, %	S, %	P, %	
1	3·5	...	...	...	...	Fig. 51
2	3·5	1·37	...	...	...	Fig. 52
3	3·5	...	0·66	...	...	Fig. 53
4	3·5	...	...	0·084	...	Fig. 54
5	3·5	1·37	0·66	...	...	Fig. 55
6	3·5	1·37	...	0·084	...	Figs. 56, 57
7	3·5	...	0·66	0·084	...	Fig. 58
8*	3·5	1·14	0·55	0·07	...	Fig. 59
9	2·9	1·37	0·66	0·084	0·29	Fig. 60

* The composition of this melt could not be calculated to that of the cupola melt with the base alloys available, and the percentage of each element, with the exception of carbon, was cut by approximately one-sixth. The carbon contents of melts 1–8 were higher by 0·6%, for the same reason.

at 1·4%, the total carbon at 3·5%, and the sulphur content was progressively increased. The melts were held at 1400° C. for 12 min. and cooled as for the synthetic series of melts. Details of the compositions and microstructures are as follows:

Melt	Sulphur by Analysis %,	Structure
1	0·08	Coarse flake graphite
2	0·11	Flake graphite plus some rather coarse undercooled type graphite
3	0·20	Undercooled plus mesh type of graphite plus some nodular graphite and carbide
4	0·30	Mesh type graphite in cluster formation plus nodular graphite and carbide
5	0·37	Carbide plus some mesh and nodular graphite

The second series of melts contained 2·25% of silicon and 3·5% of carbon, with increasing percentages of sulphur. Preparation was the same as for the previous series, but the cooling rate was a little faster. The following are details of composition and microstructure:

Melt	Sulphur by Analysis, %	Structure
1	0·06	Coarse flake graphite
2	0·09	Coarse flake graphite
3	0·36	Figs. 61–63
4	1·3	Figs. 64–71

Following this series of melts, a pure iron–carbon–silicon charge (TC, 3·5%; Si, 2·25%) was melted at 1400° C., held for 12 min., and was then water-cooled by immersing the major part of the crucible in water, but without submerging it. Micro-examination showed that the structure at the outer surfaces was white and contained an aggregate type of graphite (Fig. 72). The structure in the centre of the specimen was fine undercooled graphite (Fig. 73), and the intermediate structure was a mixture of aggregate type of graphite, carbide plates, and fine undercooled type of graphite (Fig. 74).

Figures 64–71 show some of the unusual structures which were found in the specimen containing 2·25% of silicon and 1·3% of sulphur. The specimen contained a large number of the globules shown in Figs. 64 and 65. These are iron sulphide globules containing some other phase, and probably originated at the miscibility gap which is known to occur in the iron–carbon–sulphur ternary system,[10] and which probably exists in the quaternary Fe–C–Si–S system also. A large iron sulphide inclusion is shown in Fig. 66, and smaller ones are shown in Figs. 67, 68, and 69. Most of the carbide phase was in the form of plates, as seen in Figs. 66, 68, and 69. The graphite phase occurs in many forms in this specimen, the thin films around the sulphide and carbide phases being of greatest interest. The Widmanstätten form of graphite is shown in Fig. 70 and follows the general orientation of the carbide plates. These directional effects are also seen in Fig. 69.

The occurrence of the graphite films around the sulphide and carbide phases bears considerable similarity to the occurrence of a graphite film around the defect known as cold shut in cast irons. Cold shut is produced by metal splashing into the mould and solidifying before the bulk of the metal meets it. If the following metal is not sufficiently hot to remelt the solid metal particles, then the boundary frequently consists of a thin film of graphite as shown in Fig. 75. The sulphide globule had formed from the melt, and although the sulphide was probably molten when solidification of the melt took place, comparable conditions would exist. The occurrence of graphite around the carbide lakes may suggest that this carbide formed early in the process of solidification, and it is possible that the small graphite nodules occurring in Figs. 68 and 69 originated at inclusion faces, and did not form spontaneously.

The mesh type of graphite and some graphite spherulites have been noted in high-sulphur irons containing iron sulphide.[11, 12, 13] It was suggested that these graphite structures arose because the metal solidified white and graphitized after solidification, and it was suggested that this was caused by the influence of temperature on the reaction

$$FeS + Mn \rightleftharpoons Fe + MnS.$$

However, in the cases considered in this paper, these graphite structures have been obtained in the absence of manganese, so that they cannot be attributed to this reaction, and are probably caused solely by the effect of sulphur.

DISCUSSION OF RESULTS

The experimental work described may, for the purpose of discussion, be divided into three sections. The first includes the influence of sulphur and oxygen on the mechanism of solidification of pure iron–carbon alloys, and also the influence of silicon and manganese. The second section discusses the influence of oxygen on the form of the manganese sulphide inclusions in pure iron–carbon alloys and cast irons, and the relation of the changes to the effects of inoculation and superheating. The results obtained from the synthetic production of a cast iron composition from pure materials, and the series of melts on the addition of sulphur to pure iron–carbon–silicon alloys, are considered in the third section.

The Influence of Sulphur and Oxygen on the Mechanism of Solidification of Pure Iron–Carbon Alloys

The work of Boyles[6,7] on the addition of sulphur to pure iron–carbon–silicon alloys prompted the first series of melts with increasing sulphur contents. Boyles found that as the sulphur content was increased from 0·018% to 0·294% in an alloy containing 3·49% of C and 2·01% of Si, the graphite structure became coarser and then finer. The same effect was observed in a lower carbon alloy (TC, 3·06%; Si, 1·91%), but it was found that a given percentage of sulphur exerted a greater effect.

In the present series of experiments there was no silicon, and the rate of cooling was such that the untreated alloy solidified white. As the sulphur content was increased, the alloy solidified grey with progressive coarsening of the graphite. The most uniformly large graphite flakes occurred in the alloy containing 0·01% of sulphur (Fig. 8), although larger flakes occurred in the alloy containing 0·025% of sulphur (Fig. 9), but in the latter there is also more undercooled graphite. Further increases in sulphur produced a mottled structure with 0·05%

(Fig. 10), and a completely white iron with 0·10% (Fig. 12). In general, an increase of the sulphur content has a graphitizing and then a carbide stabilizing effect, but a closer study of the micrographs reveals some interesting features. The white iron structure in the low-sulphur alloys (Figs. 1, 2, and 3) is ledeburitic in form, and is typical of a eutectic formation, with well developed primary dendrites in a laminated matrix. The white iron structure produced by 0·10% of sulphur (Figs. 12 and 13) consists of massive carbide and transformed austenite. The carbide has a distinct angular outline and the primary dendrites have a rugged appearance, as distinct from the rounded dendrites shown in Figs. 1, 2, and 3. This is caused by the deposition of the eutectic austenite on the primary austenite dendrites.

The degree of sharpness of the change in structure from the ledeburitic white iron shown in Fig. 2 to the fine graphite shown in Fig. 4 was distinct and well defined, with the exception of a small region of inverse chill (Fig. 5), whereas the reversion of structure from grey to white iron with increasing sulphur was *via* a mottled structure, as shown in Figs. 10 and 11. The carbide/graphite interface in the specimen showing inverse chill is sharp and well defined (Fig. 5). The flake graphite is uniform in size up to the interface, where there is an abrupt change to the carbide phase. No inverse chill was observed in any of the other specimens.

In the reverse change from grey iron to white iron, with increasing sulphur, there is uniform mottling (Fig. 10); and it will be observed from Fig. 11 that in moving from the centre of a grey zone to a carbide zone, the graphite becomes coarser until it merges into the carbide. Graphite flakes are seen to extend into the massive carbide (Fig. 11).

It would have been interesting to pour melts of the composition given in this series against metal chills, to determine the type and depth of mottle obtained. This would have shown whether the low-sulphur melts would have given a sharp change from white to grey, *i.e.*, a narrow mottle zone, and whether the high-sulphur melts would have given a wide mottle spread.

It is difficult to understand why sulphur should first produce a graphitizing and then a carbide stabilizing effect, even after giving due consideration to segregation, which undoubtedly occurs in the melts of higher sulphur content. If the sulphur entered into combination with some other carbide stabilizing element, neutralizing its effect at the point of maximum graphite size, then this effect could be explained, but apart from the possible presence of gases, such an element cannot be detected.

The oxygen series of experiments is comparable with the sulphur series if it is assumed that there is a certain amount of oxygen present in the iron–carbon alloys melted under atmospheric conditions, that the addition of aluminium eliminates the effect of this oxygen, and that the addition of iron oxide to the surface temporarily increases the oxygen content.

As a matter of interest, the change from undercooled graphite in the centre of the grey mottle zones shown in Fig 18 is, again, *via* a coarse flake graphite structure, at the carbide interface (*cf.* Fig. 19 with Fig. 11).

The influence of sulphur and oxygen on graphitization may be represented graphically as in Fig. 77. Owing to the lack of quantitative information (particularly of oxygen content), and the difficulty of evaluating carbide stability or degree of graphitization, the diagram is schematic and represents the general trend only. The graph would undoubtedly be modified in shape and be displaced by changes in the composition of the base alloy as well as by changes in the cooling rate.

It is not known whether sulphur and oxygen would have independent or additive effects if present together.

In the silicon series of melts, the results are interpreted as being influenced by the deoxidizing properties of this element, which must be appreciable at the temperatures at which these alloys solidify. Thus the addition of silicon would have a progressive deoxidizing effect, producing a refinement in the graphite size, culminating in the formation of some carbide in the ingot containing 0·05% of silicon. The slight coarsening of the graphite with further increases of silicon is assumed to be caused by the predominating graphitizing properties of this element.

The addition of small amounts of manganese did not produce any effects which could be attributed to its deoxidizing properties. Increasing the manganese content of melts cooled at such a rate that the untreated melt solidified grey, resulted in a white iron at approximately 0·5% of manganese (Figs. 31, 32, and 33). The carbide formed was of the massive type (Fig. 33).

A series of melts with increasing manganese additions, cooled at such a rate that the untreated melt solidified white to give the type of structure similar to that shown in Fig. 1, showed that the progressive increase in manganese produced a progressive change from the fine to the massive type of carbide, although this change did not reach completion at 0·5% of manganese, which was the maximum amount added.

The Influence of Oxygen on the Form of the Manganese Sulphide Inclusions in Cast Iron and the Relation of these Changes to the Effects of Inoculation and Superheating

The change in the form of the manganese sulphide phase was observed as a result of the addition of

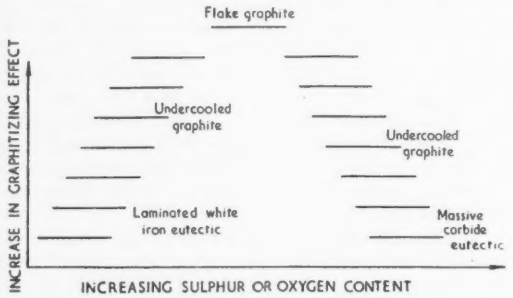


Fig. 77—Graphical representation of the graphitizing effects of sulphur and oxygen in pure iron–carbon alloys

aluminium and iron oxide to cast irons. The original intention was to determine the influence of these additions on the eutectic structure, and the experiments were based on the results obtained from the addition of aluminium and iron oxide to pure iron–carbon alloys. The addition of iron oxide changed the structure from grey to white, but this may have been caused by the drop in the silicon content. The addition of small amounts of aluminium did not produce any detectable effect on the eutectic structure, but closer examination revealed a distinct change in the form of the manganese sulphide inclusions.

Manganese sulphide occurs in cast irons as dove-grey inclusions, and Wyckoff[14] reports the crystal structure as being cubic. The inclusions are either compact, of the type shown in Figs. 35 and 36, or elongated as seen in Fig. 34. The elongated forms are frequently referred to as anchor formations, and an inclusion approaching the anchor form is shown in Fig. 40. This type is usually better developed in large castings which have cooled slowly, when the arms originating from a point grow outwards in straight lines, terminating as well developed arrow-heads. The terms 'compact' and 'elongated,' as used in this report, are very general and cover two broad types of inclusion, there being no well-defined line of demarcation. When studying elongated inclusions of the type shown in Figs. 34 and 40 it must be remembered that the plane in which the inclusions are viewed may cut through some of the arrowheads of an elongated inclusion. This is probably the reason why a few compact manganese sulphide inclusions always appear with the elongated type. In the above experiments, the addition of aluminium to an iron always gives the compact type of inclusion, and the elongated type has been completely absent in the specimens which solidified soon after treatment.

The production of the compact type of manganese sulphide inclusion in all the vacuum melts leads to the conclusion that the formation of this type of sulphide is independent of the aluminium and/or silicon present in the melt, and that the action of aluminium in producing these inclusions is that of a deoxidant, it being assumed that melting in an alumina crucible at 1400° C. *in vacuo* results in substantial deoxidation of the melt.

In the series of experiments with an oil-furnace-melted iron, an attempt was made to determine the influence of aluminium and iron oxide additions, using larger amounts of metal than in the laboratory experiments. The equivalent aluminium or oxygen addition would be larger, and it was thought that closer control of these additions would thus be possible. Furthermore, the effect of these additions on the chilling properties of the iron was studied by means of chill wedge castings. It was thought that a study of the chill depth and type of mottle produced in a chill wedge by aluminium or oxygen additions would reveal more information than that obtained from the 10-g. melts.

The oil-furnace melts consistently gave the elongated type of manganese sulphide. The addition of aluminium consistently gave the compact type of inclusion, but the addition of iron oxide powder to the ladle, or hematite ore to the melting crucible, did not produce the compact type of inclusion as in the 10-g. melts of cast iron treated with iron oxide (Fig. 36). Little information was obtained on the effects of the oxide additions on chilling tendencies, since all the wedges were white.

The observed occurrence of the compact type of inclusion in the oil-furnace melt, to which the ferro-silicon of the charge was made as a late addition, led to the inoculation of the melts with aluminium or ferro-silicon after normal melting of the charge from cold.

The relationship between inoculating effect, time, and corresponding change in the type of manganese sulphide inclusions is clearly shown in Figs. 39–46. Figure 41 has been included to show the similarity in the type of manganese sulphide produced by the additions of 0·01% of aluminium and that produced by an addition of 0·5% of ferro-silicon. The reduction of chill by the aluminium addition is not as great as that produced by the ferro-silicon (*cf.* wedges Nos. 2 and 3, Fig. 39), but due consideration must be given to the increase in silicon content produced by inoculation with ferro-silicon.

If the inoculated metal is held for 25 min. there is an increase in chill (*cf.* wedge No. 5 with wedge No. 4, Fig. 39), and the manganese sulphide inclusions become larger (*cf.* Fig. 44 with Fig. 43). A further 25 min. increases the chill (wedge No. 6, Fig. 39), and the manganese sulphide inclusions are much larger, with a tendency towards an elongated form (Fig. 45). Yet another 25 min. gives the elongated type of manganese sulphide with very little change in chilling properties. Wedge No. 7 shows some grey mottle, whereas wedge No. 1 is completely white, but the manganese sulphide is of the elongated type in each case. The only apparent difference between these two wedges is the silicon content, which may account for the difference in chill.

Similar results were obtained in the melt inoculated with aluminium only. The graphitizing effect was less than that produced by ferro-silicon, but the changes in type of manganese sulphide inclusion were the same.

As inoculation and superheating are phenomena of a converse but similar nature, experiments were made to determine whether some relationship existed between the chill-producing effect of superheating and the type of manganese sulphide forming in the melts. Experiments to date have confirmed the reported complex nature of the effects of superheating. All the experiments show that superheating increases the chilling tendencies of the iron, and also changes the form of the manganese sulphide inclusions. If the change of form of the manganese sulphide inclusions is caused by a change in the oxygen content of the melt, then superheating must influence the oxygen content, which in turn has an influence on the chilling properties. Further work on the effect of superheating will have to be conducted under very closely controlled conditions, before results of a comparative value will be obtained. Particular attention will have to be applied to the condition of the charge, the nature of the refractory, and the time and temperature of superheating.

Schneble and Chipman[5] give a comprehensive

account and bibliography of known work, and as a result of their experiments they conclude that the effects of superheating are not due to nucleation processes, but to the gases present in the metal, and, in particular, to carbon monoxide.

Based on the results of the present experimental work, it is suggested that the effects produced by inoculation and superheating are caused mainly by the oxygen present in the iron. If the iron to be inoculated or superheated has attained a state of chemical equilibrium, it may be assumed that inoculation or superheating will displace the equilibrium, and that the change in properties with time and temperature is caused by a gradual return to the original state. In the case of inoculation, the deoxidized metal gradually regains oxygen, and the effect of inoculation wears off. In the case of superheating, oxygen is either gained or lost to attain the new state of equilibrium. Such gains or losses are reflected in a change in the form of the manganese sulphide inclusions, and it is suggested that some of the oxygen in cast iron is present in these inclusions as the oxide of iron and/or manganese. If the manganese sulphide inclusions are a complex of manganese sulphide, iron sulphide, manganese oxide, and iron oxide, then changes in composition will alter their mechanism of solidification. In all the hypo-eutectic white iron structures which have formed, there is a definite tendency for the elongated manganese sulphide to be associated with the primary dendrites (Figs. 34, 40, 46, and 48) and for the compact type of inclusions to occur in the white eutectic (Figs. 36, 49, and 50). This is more pronounced visually in the white than in the grey irons. It is not certain that the simultaneous growth of the primary dendrites gives rise to the elongated form of manganese sulphide. The angular arrowheads appear to form when the inclusions enter the eutectic zone (Figs. 40 and 46).

The results of the pure iron–carbon melts show that oxygen has a graphitizing or carbide stabilizing effect, depending upon the the amount present, and the effect has been represented schematically in Fig. 77. When it is realized that oxygen and sulphur may produce these effects and that segregation of these elements is possible during cooling, it is not surprising that so many anomalous structures occur in cast irons.

The curves obtained by Schneble and Chipman[5] for tensile strength plotted against time and also against temperature of superheating, are of the same general form as the curve proposed in Fig. 77. The curves obtained by Sims and Dahle[15] on the effect of aluminium on ductility and impact strength of cast steels are also of the same form. These investigators also found that additions of small amounts of aluminium to steels which had been killed with silicon and manganese modified the form of the manganese sulphide inclusions, changing them from a compact to an elongated form, and then to a compact form, with progressive increases of aluminium. The authors state that the critical quantity of aluminium which will produce minimum ductility is that which gives complete deoxidation without leaving an appreciable excess of aluminium. This amount of aluminium also produces the elongated manganese sulphide inclusions at the grain boundaries, and the conclusion is that the decrease in ductility is due to this elongated form of manganese sulphide. The fact that the decrease in ductility is less pronounced in the low-sulphur steels supports this. The authors also found that excess of aluminium gave black inclusions, which they consider to be Al_2S_3.

Recently, Heine[16] has reported work on some of the effects of deoxidation treatments on the graphitization of white cast iron. Heine found that the manganese sulphide inclusions in the untreated iron were of the compact type, and that increasing additions of aluminium changed the form to the elongated and then to the compact type, in direct comparison with the findings of Sims and Dahle, and suggests that deoxidation is complete with the amount of aluminium which produces the elongated type of manganese sulphide inclusions. It must, therefore, be assumed that further modification of the manganese sulphide from the elongated to the compact type by further increases of aluminium is caused directly by the aluminium.

This assumption is not in agreement with the results of the present investigation, in which melting conditions happened to be such that the elongated type of manganese sulphide was formed in the as-melted iron. Additions of aluminium to this iron gave the compact type of inclusion. As vacuum melting also changed the elongated to the compact type of inclusion, it is most probable that the elongated form of manganese sulphide in cast iron does not coincide with complete deoxidation. Heine also found that additions of 0·03% of aluminium gave black inclusions associated with the manganese sulphide, and which Sims and Dahle consider to be Al_2S_3.

In the present investigation, similar additions of aluminium were made to cast iron, but the black inclusions were not observed on micro-examination. Examination at high magnifications revealed some duplex inclusions, one of which is shown in Fig. 76. The second phase was darker than the manganese sulphide, but did not appear black upon visual examination.

A study of the results in the present investigation reveals one apparently anomalous result. The addition of a small amount of aluminium to a pure iron–carbon alloy or pure iron–carbon–manganese–sulphur alloy, has a carbide stabilizing effect, whereas the addition of small amounts of aluminium to cast iron has a graphitizing effect, both of which are in direct contrast to one another. When considering this effect of aluminium, allowance has to be made for the basic difference of the two alloys.

Work on the inoculation or superheating of cast iron almost invariably provokes some discussion of the theories which have originated and developed with the study of these phenomena. Although the present investigation shows that oxygen plays an important part in the effects of inoculation and superheating, other factors almost certainly have their particular influence, and of these, sulphur gives rise to considerable speculation.

Owing to the nature of the experimental procedure and the limitations of present-day chemical methods, quantitative information, particularly on the oxygen

contents of the melts, is entirely absent. The effects attributed to oxygen are therefore based on circumstantial evidence only. The work has shown, however, that a study of the type of manganese sulphide inclusions in cast iron may provide a useful guide to the ' state ' of the iron.

The Synthetic Production of Cast Iron and the Addition of Sulphur to Pure Iron–Carbon–Silicon Melts

The synthetic series of melts shows the interesting effects produced by the individual and combined addition of the elements silicon, manganese, and sulphur.

Increasing the silicon alone in the pure iron–carbon alloys does not appear to have a pronounced graphite-coarsening effect. The graphite flakes are slightly coarser, but are of the undercooled variety (*cf.* Figs. 51 and 52). The addition of manganese alone has a carbide stabilizing effect (Fig. 53), but this effect is eliminated by the inclusion of silicon, giving a somewhat coarser graphite than that produced by silicon alone (*cf.* Figs. 52 and 55). It is inferred from these structures that silicon alone, although regarded as a graphitizing element, does not produce coarse flake graphite, but its graphitizing effect overcomes the carbide stabilizing effect of manganese alone, and also of sulphur alone (*cf.* Figs. 54 and 56).

Manganese and sulphur alone have a carbide stabilizing effect (Figs. 53 and 54), but the combination of these two elements gives undercooled graphite (Fig. 58).

Normal flake graphite only appears when silicon, sulphur, and manganese are added together. This specimen is also mottled, and some of the white iron is shown in Fig. 59. These results, obtained by the addition of silicon plus manganese plus sulphur, are in agreement with Boyles' results. Boyles[6,7] found that undercooled graphite invariably formed in the pure iron–carbon–silicon alloys, and he concluded that the flake graphite structure associated with commercial irons is caused by the presence of sulphur or sulphur plus manganese.

The re-melted cupola iron which solidified white (Fig. 60) is not of the same composition as the synthetic alloy (Fig. 59), and the original objective, which was the synthesis of this composition, was not fully attained.

The occurrence of nodular and mesh type graphite was unexpected in the pure iron–carbon–silicon alloys treated with sulphur. Boyles,[7] in his series of experiments on the influence of increasing sulphur additions to pure iron–carbon–silicon melts, did not report this type of structure, although some of the compositions are very similar. The different cooling rates would probably account for the different structures. In the present series of experiments, the nodular and mesh type graphite produced by sulphur was only observed in the pure iron–carbon–silicon series and not in the pure iron–carbon series of melts.

SUMMARY AND CONCLUSIONS

The addition of small percentages of sulphur to hypo-eutectic pure iron–carbon melts has a graphitizing and then a carbide stabilizing effect. The carbide formed in the presence of sulphur differs from that produced in the absence of sulphur. The change from the white to the grey structure with increasing sulphur is abrupt, but the reverse change from grey to white with increasing sulphur is *via* a mottled structure.

Oxygen has an effect almost identical with that of sulphur. The experimental evidence, although lacking quantitative information, suggests that increasing the oxygen content of pure iron–carbon melts has a graphitizing and then a carbide stabilizing effect. The carbide forming in the deoxidized melt differs from that produced in the oxidized melt. These changes in carbide (eutectic) structure are very similar to the changes produced in the sulphur series of melts.

Small additions of silicon to pure iron–carbon melts have a slight carbide stabilizing and then a slight graphitizing effect, which is assumed to be caused by the effect of the silicon on the oxygen content of the melt.

Additions of small amounts of aluminium and oxygen to 10-g. melts prepared from cupola iron, change the form of the manganese sulphide inclusions. The untreated iron gave the elongated type of manganese sulphide. Treatment with aluminium gave the compact type of manganese sulphide, and the addition of iron oxide powder (Fe_3O_4) also gave a compact type of manganese sulphide.

Vacuum melting confirms that the action of aluminium in producing the compact type of manganese sulphide inclusions is caused by its deoxidizing effect and not because the aluminium has a direct effect on the sulphide.

The inoculation of cast iron with aluminium or ferro-silicon also changes the elongated type of manganese sulphide to the compact type, and it has been clearly shown that the diminishing effect of inoculation on chill removal, which results if the inoculated metal is held, is reflected in a general reversion from the compact to the elongated type of manganese sulphide originally occurring in the untreated melt.

Superheating also changes the form of the manganese sulphide inclusions, there being a change from the elongated to the compact type of sulphide on superheating from temperatures of about 1450° C. to 1500° C. and higher. The determination of the relationship between time and temperature of superheating, chill production, and change in form of the manganese sulphide requires considerable further investigation.

It is suggested that the effects of inoculation and superheating are governed primarily by the changing oxygen contents of the melts.

The synthetic production of a cast iron from pure constituents has resulted in the production of many interesting structures. Silicon plus manganese plus sulphur are necessary for the production of the flake type of graphite normally associated with grey iron. Manganese and sulphur alone are carbide stabilizers, but the addition of both together has a graphitizing effect. Silicon alone does not appear to produce any appreciable graphite-coarsening effect, and does not eliminate the undercooled graphite, but it is very effective in eliminating the carbide stabilizing effects

of both manganese and sulphur. Silicon and sulphur together produce some nodular graphite structures.

The comments apply only to the particular compositions and cooling rates described in the text.

Acknowledgments

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A Note on the Overheating of Steel

By E. C. Rollason, M.Sc., Ph.D., F.I.M., and D. F. T. Roberts, B.Sc.(Tech.)

SYNOPSIS

From existing published data on overheating it has been concluded that the amount of manganese sulphide present in a steel is an important criterion of the minimum overheating temperature. A new graphical presentation of the data shows that the overheating temperature is a function of sulphur content and Mn/S ratio, and this helps to elucidate anomalous results.

THE cause of overheating in steel has recently received much attention,[1, 2] and it is generally accepted that it is partly associated with the inclusion content of the steel. Woolman and Kirkby[2] have suggested a hypothesis based on the solution, diffusion, and precipitation phenomena of some element or compound which, however, is unnamed. Examination of these data has indicated that manganese sulphide content is an important factor, and a new graphical presentation was derived which helps to elucidate some of the anomalous results given in the papers. Some hesitation was felt in suggesting this until Ko[3] recently provided direct evidence of the influence of manganese sulphide on the overheating temperature.

Preece[1] obtained good agreement between the incipient overheating temperatures and the inclusion counts of the steels, with the exception of a few anomalies. While it is appreciated that it is difficult to get a quantitative measurement of inclusions in steel, Preece states that this aspect was checked by two observers and agreement was satisfactory. The present authors, therefore, considered it reasonably safe to use these inclusion counts in graphs against sulphur, oxygen, S + O, and S + 2O, in order to find which combination was important. The plots produced wide bands indicating poor correlation.

INTERPRETATION OF EXPERIMENTAL RESULTS

In Fig. 1, line *AB* represents the maximum number of inclusions for a given sulphur content, and extrapolation is sufficiently close to the origin to be significant. Points to the left of *AB* may therefore be considered to represent steels with fewer inclusions than the maximum possible; and therefore sulphur exists in solution or in small inclusions which escape counting. Each point can be assumed to be associated with a 'sulphur discrepancy,' *i.e.*, the amount of sulphur unaccounted for in the inclusion count. This sulphur discrepancy was plotted against the Mn/S ratio for each steel, since Whiteley[4] has shown that at the melting point of the steel the form of the sulphide is a function of this ratio. Figure 2 indicates,

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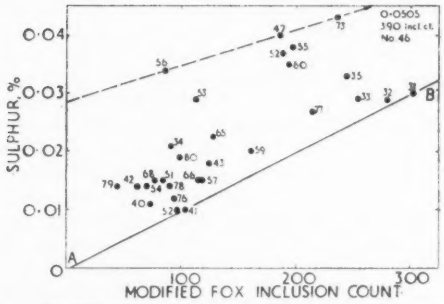

Fig. 1—Modified Fox Inclusion Count plotted against sulphur content. The number by each point is that of Preece's sample

at Mn/S = O, a good agreement with the reported[5] solubility of FeS (0·02–0·03% of S) at about 1300° C. Since, according to Whiteley, all the sulphur should exist as manganese sulphide when the Mn/S ratio exceeds a value of 20 (approx.), some MnS must be soluble or very finely dispersed, because a ratio of 70 is indicated in Fig. 2 as necessary for the complete insolubility of sulphur. When the points in Fig. 2 were examined in the light of their associated overheating temperatures, it appeared likely that the overheating temperature of a given steel might be a function of its Mn/S ratio and sulphur content.

Figure 3 shows the result of plotting the reported results[1, 2] in this manner. The curves have been drawn to indicate 1300° and 1400° C. overheating temperatures. At the lower temperature of 1300° C., however, a better agreement would appear to exist if the steels were separated into :

(1) Low-alloy steels containing less than 2% of nickel or chromium
(2) High-alloy steels containing more than 2% of nickel or chromium, or 0·4% of carbon.

The 1300° C. curve for the high-alloy group of steels is displaced to the left, *i.e.*, the sulphur content is related to a lower Mn/S ratio than that for the corresponding curve for the low-alloy group. From unpublished work on the effect of nickel in reducing the solubility of sulphur in weld metals, it is thought that it would be profitable if further work on overheating took into account the influence of nickel.

From Fig. 3 it will be noted that when the Mn/S ratio exceeds about 20, the overheating temperature does not vary greatly with the Mn/S ratio, but is raised as the sulphur content increases. This suggests that the constant overheating-temperature curves

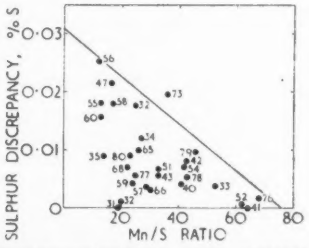

Fig. 2—Manganese/sulphur ratio plotted against sulphur discrepancy from Fig. 1

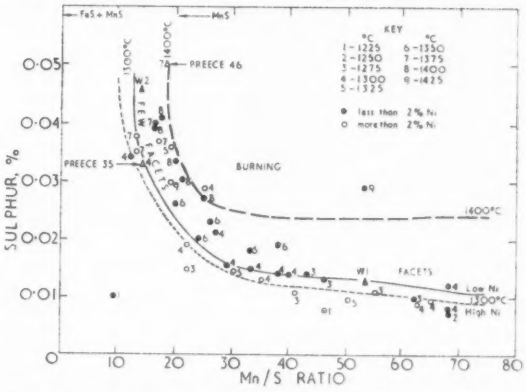

Fig. 3—Manganese/sulphur ratio plotted against sulphur content. The single figures by the points refer to the overheating temperature of the steel

correspond to definite manganese sulphide contents. This idea is supported further if Whiteley's results for the MnS/FeS ratio at the melting point of steel are used to obtain curves relating the sulphur content and the Mn/S ratio for definite amounts of sulphur as Mn/S, as shown in Fig. 4. There is a close similarity between Fig. 3 and Fig. 4. The rise in the curves when the Mn/S ratio is less than 20 can be explained by the fact that increasing quantities of FeS (or sulphur in solution) exist as the Mn/S ratio decreases : thus the constant MnS content corresponds to a higher percentage of sulphur.

HYPOTHESIS

Manganese as estimated by chemical analysis can exist in several different forms in a steel, *e.g.*, in solution, or as manganese oxide, manganese silicate, and manganese sulphide. The oxygen content of a steel may therefore affect the amount of MnS present in a steel. The oxygen content of the overheated steels under discussion is insufficient to greatly affect the amount of MnS, but may be the cause of some of the minor discrepancies.

Manganese sulphide in steel may be considered as being formed under two different conditions. Given suitable conditions, MnS can form in a steel above its freezing point. Just below the freezing point some manganese is located in inclusions (as MnS or MnO). The remainder will exist as a solid solution of manganese and iron. As the temperature

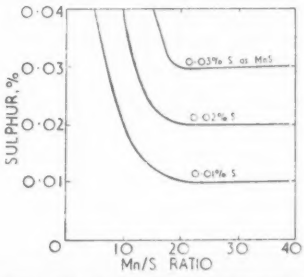

Fig. 4—Curves of constant manganese sulphide, at 1500° C. (from Whiteley's results)

decreases from the freezing point of the steel, the MnS/FeS distribution alters and more MnS can be precipitated. This MnS or (Fe,Mn)S can be redissolved in the steel if the temperature is raised above 1250° C. Andrew and Binnie,[6] and Whiteley,[7] have shown that MnS is only slightly soluble at 1250° C. and it is interesting to note that no steels have been reported as overheating at much lower temperatures.

It is considered, therefore, that the amount of soluble MnS largely controls the minimum overheating temperature, which corresponds to some temperature at which this MnS is in solution.

This is an essential requirement, since particles of undissolved MnS will act as nuclei on which the soluble MnS is precipitated when the steel is cooled. This will tend to maintain a random distribution of MnS instead of preferential precipitation at a grain boundary. The greater the quantity of MnS present in a steel, the higher is the temperature required for completion of solution, and therefore the higher the overheating temperature. On the other hand, a condition may be reached when the total MnS is so small in amount, relative to the austenite grain boundary area, that the degree of overheating exhibited, after treatment at the temperature corresponding to complete solution of MnS, is too poorly defined to enable the critical temperature to be estimated. At higher temperatures grain growth will reduce the area over which MnS has to be precipitated and will intensify the phenomena (*see* example given by Woolman, p. 268P).

Whiteley[7] has shown that the diffusion of manganese in steel up to 1350° C. is very slow. The manganese from the MnS which is just dissolved might therefore be considered as largely immobile. The sulphur, however, would be expected to diffuse more readily, and to concentrate near the austenite grain boundaries. If the steel is then rapidly cooled, much of this sulphur is retained in solid solution in the steel, and overheating phenomena are not exhibited.

A somewhat slower rate of cooling would enable the sulphur to combine with manganese atoms in the vicinity to form minute particles of MnS, the greatest quantity being in a band around the grain boundaries. These particles affect cohesion of the grains, *i.e.*, they form faceted fractures and affect etching by setting up galvanic action.

Still slower rates of cooling would produce fewer nuclei, and also enable coagulation of particles to occur; these larger inclusions have less influence on the properties of the steel. This coagulation would also occur at normalizing temperature, but so slowly that repeated heat-treatment would be necessary to efface overheating effects.

EXPLANATION OF ANOMALOUS RESULTS

In Preece's Fig. 6 good agreement was shown to exist between the inclusion count and overheating temperature except for two steels, No. 35 and No. 46. These two results, however, fit in with the curves shown in Fig. 3.

Woolman (p. 279P) reported that the treatment of an ingot with iron sulphide, in order to produce a sulphur content comparable with that of a Siemens cast, failed to show any difference in the minimum overheating temperature. These two results, marked *W*1 and *W*2 in Fig. 3, fit the curves and can be explained by the low Mn/S ratio of the steel having a high sulphur content. Consequently, the amount of MnS is much the same in both ingots, the additional sulphur existing as FeS. In the case of Preece's results, FeS would increase the number of inclusions without affecting the overheating temperature.

In the case of high-sulphur free-cutting steels, although the Mn/S ratio is about 5, and the large bulk of the sulphur exists as FeS, the amount of MnS is still greater than that required for the 1400° C. curve. Therefore, no overheating phenomena are likely to occur.

Faceted fractures appear to be associated with steels having an Mn/S ratio > 20, whilst fractures with few facets occur when FeS is also present, *i.e.*, Mn/S ratio < 20.

Size of Ingot

There is some indication that the cooling rate of the original ingot influences the susceptibility of a steel to overheating. Small ingots are likely to cool more rapidly than large ones, and equilibrium in the MnS/FeS distribution is not likely to be attained, and the amount of MnS will be low. On subsequent hot working, an approach to equilibrium will cause the precipitation of MnS as finer particles than would have formed in a slowly cooled casting.

It is suggested, therefore, that in small ingots (Honeyman[8]), the smaller particles of MnS would be expected to dissolve at a lower temperature than would the larger particles in the steel from the slowly cooled ingot. This is likely to be significant only when ingots differ greatly in size.

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"Detection of Overheating and Burning in Steel by Microscopical Methods," by Preece and Nutting (1950, vol. 164, Jan., pp. 46–50).

"Grain-Boundary Phenomena in Severely Heated Steel," by Ko and Hanson (1950, vol. 164, Jan., pp. 51–62).

B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

The Traffic of Iron and Steel Works

THE APPLICATION OF VERY HIGH-FREQUENCY RADIO COMMUNICATION

By H. H. Mardon, B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.I.Struct.E., M.Am.S.C.E., H. A. Chapman, B.Sc., and M. D. Brisby, Ing.Dipl., S.I.A.

SYNOPSIS

This paper briefly examines the present methods of operating rail traffic in iron and steel works and concludes that many advantages can accrue from the use of radio communication within the system.

Facilities for very high-frequency (VHF) radio communication already exist under the control of the G.P.O., and available equipment and operating procedure are reviewed in some detail in the light of the known requirements of the iron and steel industry. Mobile transmitter powers might be reduced below the present available level of 10 W., but further work will be necessary before a firm recommendation can be made.

The question of power supplies is examined in detail, and a 350-W. steam turbo-generator, as at present in use on British Railways, is suggested as a power unit for steelworks steam locomotives equipped with radio.

Brief details of probable costs are included.

THE necessity for a detailed investigation into the traffic of iron and steel works has been felt for some time. An idea of the complex working and the difficulty of communicating messages between the various sections of the traffic organization may be gathered by studying the two very different railway layouts shown in Figs. 1 and 2.

In a paper entitled "*The Layout of Integrated Iron and Steel Works*,"[1] Mardon and Terrington drew particular attention to the need for 'streamlining' the various processes following the principles of materials flow, and considerable stress was laid on the advantages of a layout which was easily workable and capable of future expansion. The first criterion of a good layout is that the relative positions of the buildings should permit the easy handling of materials within and between these buildings. Because of the very heavy nature of the industry, the majority of the transport is handled by rail, and a good works layout must therefore have a good railway system.

Following this paper, a series of investigations was started on the traffic of works. A preliminary investigation by Mardon and Brisby[2] enabled the traffic efficiency of a works to be estimated, and brought to notice the fact that little more than half the locomotive shift time is actually spent working. Because of this low use-factor, and in view of the growing importance of radio in industrial communications, the authors have investigated the possibility of speeding the traffic of iron and steel works by means of radio traffic communication. This third paper examines the facilities available.

PART I—TRAFFIC ORGANIZATION IN THE IRON AND STEEL INDUSTRY

General

In the course of the last thirty years the production figure for steel in Great Britain has risen from 8 million tons to 15 million tons per annum. To meet this rapid increase in demand, works throughout the country have expanded to the very limits of the available areas. Relatively few completely new works have been laid out because of the large capital expenditure involved.

In some cases the development has been systematically planned, but often expansion has been carried out to meet an immediate requirement and long-term planning has not been possible.[1] This has meant that

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Mr. Mardon, Mr. Chapman, and Mr. Brisby are on the staff of the Plant Engineering Division of the British Iron and Steel Research Association.

it has not, in general, been possible to attain the most efficient material flow and transport facilities, and it was not until the advent of some of the large new integrated works that the idea started of building a works around a railway system.[1]

The high production figures of recent years have had the inevitable consequence that traffic density has gone up and freedom of movement has greatly decreased. To keep materials flowing and production figures high during the war years special emphasis was laid on the necessity for the rapid turn-round of wagons and, in Britain, the new standage scheme was introduced in place of the old demurrage regulations.[3] This scheme, in which standage charges are paid on average, and in which credits for the rapidly unloaded wagons help to pay for the idlers, has very considerably speeded-up wagon turn-round.[2]

The detailed study of traffic conditions carried out at a number of works[2] has shown that the general traffic efficiency is still low in some cases. The study comprised a detailed investigation of wagon and locomotive utilization and showed that, in some works, wagons remain loaded for up to 3½ to 4 days and that locomotives are rarely usefully employed for more than half their shift time. When it is considered that a terminal user time of 3½ days on 2000 wagons per week means an annual standage payment of £25,000, and that a locomotive costs upwards of £1 per hour, it will be appreciated that every effort should be made to reduce these costs.

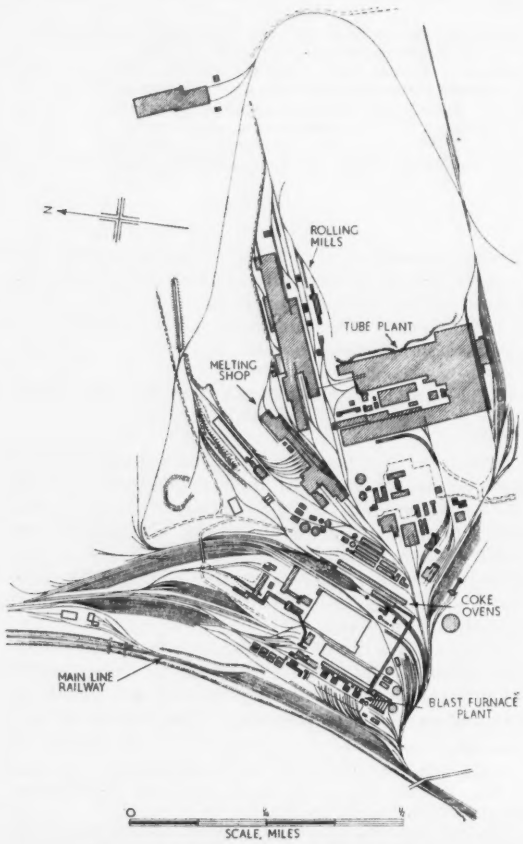

Fig. 1—Railway layout of works N

Production capacity depends largely on the facilities for materials handling, in particular rail traffic, and if worthwhile improvements are to be brought about in the transport systems of iron and steel works, without large capital expenditure for major engineering alterations, it is essential to operate the existing layouts at the highest possible efficiency.

Present Practice

Works in this country vary greatly with regard to size, layout, raw materials consumed, and finished products dispatched. There are, however, certain traffic factors which make comparison possible between the traffic systems at different works. Figures such as the numbers of locomotives per ton of output, the mileage of sidings, the total track mileage per ton of output, the number of locomotives per mile of track, standage and terminal user time in relation to the works terminal facilities, the number of locomotives per foreman, etc., all contribute to form a measure by which traffic efficiency can be assessed.

Broadly, there are two main methods of organizing the traffic department in large works : (1) The traffic manager is in charge of all locomotives, in which case he controls a number of foremen, each in charge of, say, three locomotive drivers and their shunters ; or (2) he does not have complete jurisdiction, since certain locomotives, allocated to special duties such as steelplant and mill traffic, come under the departmental managers.

It should also be mentioned that locomotive working varies from works to works. In some cases locomotives are allocated to particular duties and in others they are given comparative freedom to operate within certain areas.

Traffic managers are responsible for seeing that the various process departments get the transport service required when they need it. They also negotiate with the railways and are responsible for arranging mutually suitable deliveries. Based on the departmental requirements, they decide standage, the unloading of wagons, and stocking.

Programmed Locomotive Duties and the Need for Improved Communications

Modern methods of planning are being adapted with benefit to the iron and steel industry. Programmed locomotive working can reduce considerably the more obvious delays by arranging for the various duties to be carried out in a rational way ; for instance, by seeing that jobs in certain areas are done in the best sequence and by the correct locomotive. Programming will thus help to keep standing time low, to increase tonnages, and to facilitate good supervision for the foreman.

However, even the most careful programming of locomotive duties can do little to reduce unexpected delays. If locomotive availability is to be substantially increased, improved communication between the drivers and traffic manager or foreman must be provided.

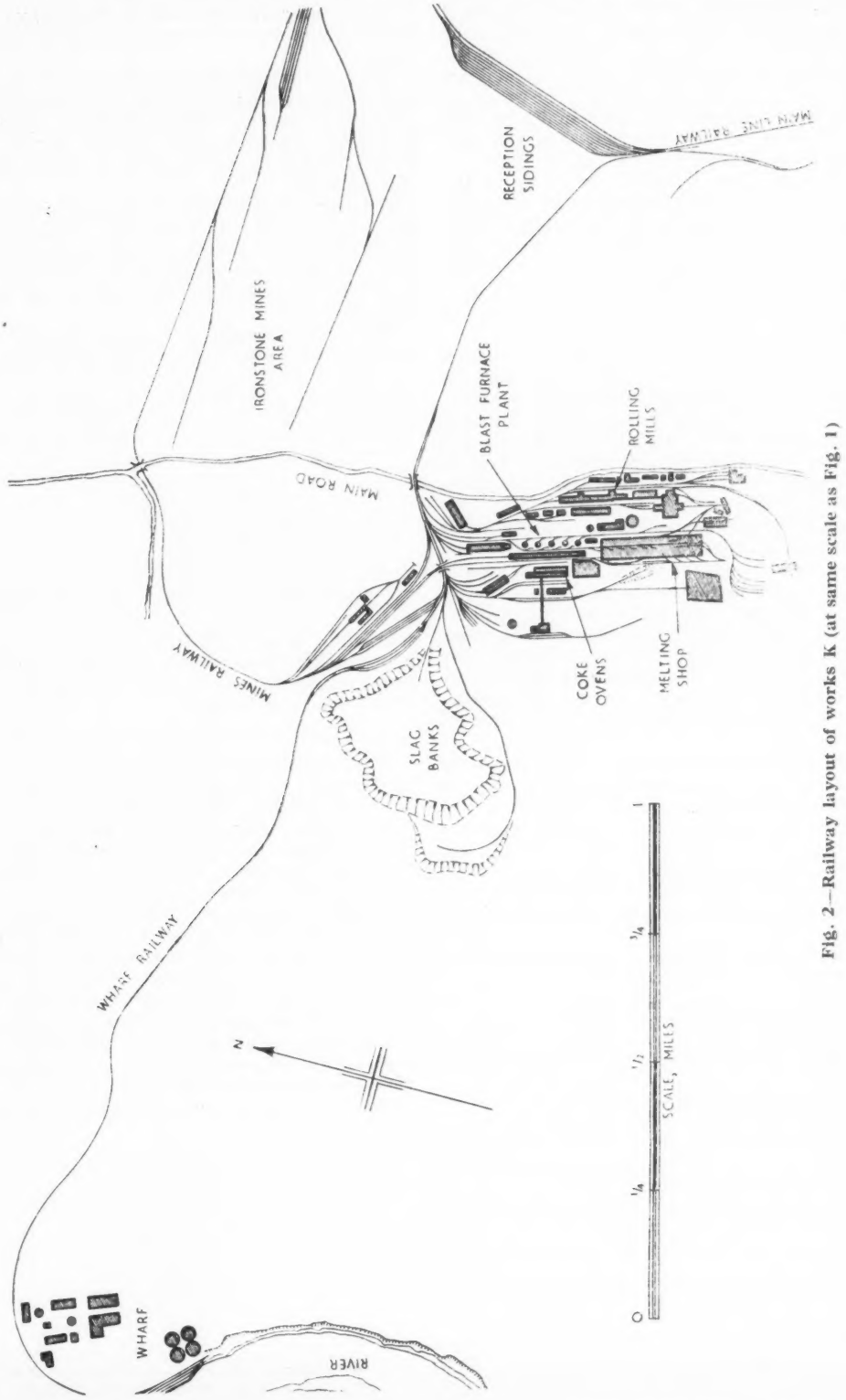

Fig. 2—Railway layout of works K (at same scale as Fig. 1)

From investigations made at a number of works,[2] it would appear that improved traffic communications would, in addition to increasing locomotive availability, speed-up the traffic system as a whole, cut down standage, and speed-up turn-round. The study of locomotive utilization showed[2] that standing-by time amounts to about 20% of the shift time and that delays amount to a further 10–15% of the time.

There is also, upon occasion, doubt as to the necessity for some of the shunting which is carried out in works. Here again a true knowledge of the departmental requirements and the careful programming of locomotive working to suit the traffic needs and the sidings and track layout, can reduce the number of shunts and give greater freedom of movement.

Although increased supervision and co-ordination between drivers and shunters considerably improves traffic operation by reducing unnecessary working, it cannot seriously remedy standing, and it cannot handle unexpected delays and emergencies. To deal satisfactorily with these it is necessary to improve the interchange of information within the traffic organization.

Ordinary telephones or speaking tubes placed about the works are not entirely satisfactory since they rely on a driver or shunter hearing the call signal, and in any case the driver would have to leave his locomotive to make or answer a call. Industrial public-address systems have some advantages over the telephone, but such a high acoustic output would be necessary to reach any locomotive driver that the disturbance factor to the rest of the works would be prohibitive. In addition, two-way communication is not normally possible.

To overcome these difficulties a system of communication between one or more control points and the locomotives is required. There are several possibilities, but only one of these, *viz.*, very high-frequency (VHF) radio, is at present giving a satisfactory communication service in many fields. It is with the possibilities of its application to traffic communications in iron and steel works that the present paper is concerned.

The principal benefits claimed by the users of radio communication on locomotives[4–16] are :

(1) Increased locomotive availability
(2) Efficient handling of emergencies
(3) Reduction of shunting
(4) More efficient working, especially at night and in fog.

Considerable thought has been given to the possibility of using radio traffic communication in iron and steel works to achieve these benefits, and in the following pages some of the systems of working and the equipment available are reviewed.

PART II—CAPABILITIES AND APPLICATIONS OF VHF RADIO

Characteristics and Range of VHF Radio Waves

The VHF radio spectrum extends from 30 to 300 Mc./sec. At these very short wavelengths the waves travel in straight lines between transmitters and receivers. The theoretical range of transmission is limited to the optical horizon or line-of-sight due to the curvature of the earth, but in practice, owing to secondary effects, it is possible for the energy to reach the receiver at distances some 25% beyond the visual range.

The actual range depends, to a great extent, on the intervening topographical features between the transmitter and receiver. Whilst ground reception with VHF radio is possible up to 50 miles over the sea or very flat land, this becomes much less in hilly or built-up areas.

The range of an installation increases rapidly with the height of the transmitting aerial, as shown qualitatively in Fig. 3 ; hence the aerials of a steelworks system should always be mounted at a height that will ensure satisfactory coverage of the area required.

The signal strength at a given distance from a transmitter is proportional to the square root of the transmitter power. Thus relatively large increases in transmitter power are necessary to provide the increased signal strengths required to bring about an effective increase in range.

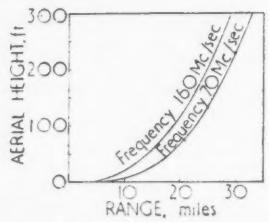

Fig. 3—Variation of range with aerial height

Radio Coverage and Reception in Built-up Areas

By radio coverage is meant the entire area in which intelligible reception from a fixed central transmitting station is possible. The term generally implies complete coverage, or an absence of ' blind spots.'

In built-up areas, the effect of buildings, particularly steel-framed buildings, in the path of the waves is to form shadows. These shadows are more marked at the higher frequencies. However, owing to the property of VHF waves of being reflected by conducting surfaces, these shadows are seldom clearly defined, and only a weakening of the signal is observed, as shown in Fig. 4. Thus reception is possible close up against and even inside steel-framed buildings.[17]

Although it is not possible to give precise figures, satisfactory radio coverage in heavily built-up areas should be possible over ranges up to 10 miles with a single fixed-station aerial mounted 30–40 ft. high,

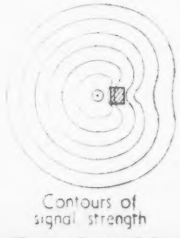

Fig. 4—General effect of steel-framed building or other large screen on field strength

using transmitter powers not greater than the limit allowed by the G.P.O.[18]

Present-Day Applications

Requirements of the Services during the late war were largely responsible for the rapid growth of VHF radio as a means of providing direct two-way speech between a point of control and any number of mobile operational units. Multi-channel equipment for aircraft and tanks reached a very high standard of performance, and for some years police forces throughout this country and in other parts of the world have been equipped with cars carrying VHF radio as a means of intercommunication.

The post-war period has seen the introduction of VHF radio into many industrial, public utility, and commercial spheres, such as the gas industry, taxicabs, electricity undertakings, newspapers, etc., and in general the equipment has given satisfactory service and has resulted in increased efficiency and economy. It is understood, however, that with increased demands on the limited numbers of frequencies available, the quality of service obtained is liable to become less satisfactory.

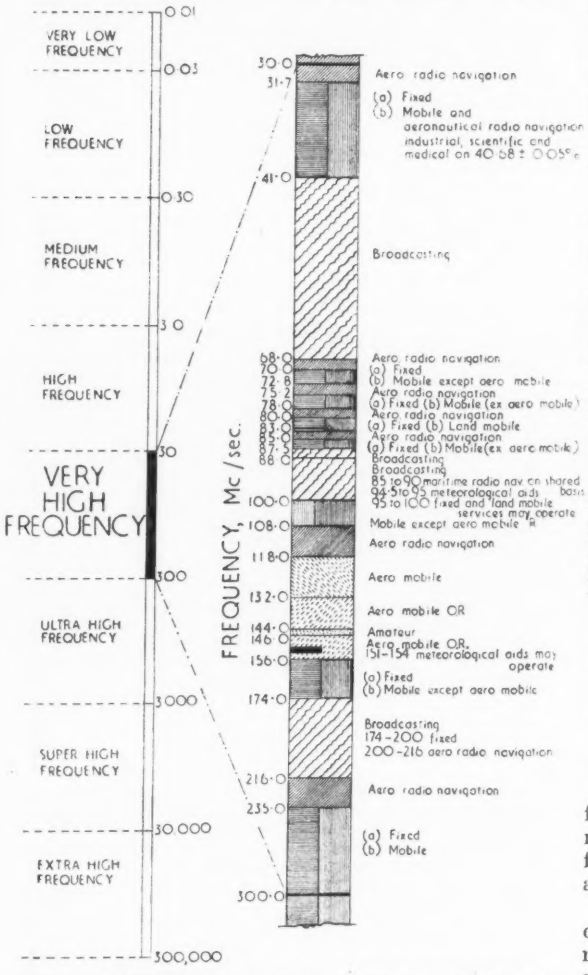

Fig. 5—Classification of radio waves and details of frequency allocations in VHF band (Europe)

In the marine field VHF radio is used to control the operations of tug boats and pilots. A public system, connected to the telephone network, is being operated in the Thames Basin by the G.P.O., and plans are well advanced for a private scheme on the Mersey, not connected to the telephone network.

Another recent application[4] facilitates the movement of freight traffic through the Whitemoor marshalling yard of the Eastern Region of British Railways.

In Britain one large iron and steel works is using VHF radio as a means of communication between a central control point and the wing trippers and ore reclaiming machines.[19] Several other iron and steel works are considering the use of VHF radio for locomotive traffic communications, and tests have already been carried out at some of these works.

Considerable application of VHF radio has been made in the U.S.A., where it is in use in at least one large iron and steel works.[9]

Frequency and Licence Conditions

The G.P.O. is responsible for controlling all civilian radio communication services in the United Kingdom. Explanatory memoranda[20, 21] and application forms[22] for licences for private short-range radio services for business purposes are obtainable from the Overseas Telecommunications Department (Tp. and R.B.), G.P.O. Headquarters, London, E.C.1.

Owing to a shortage of radio frequencies, radio is not available for services which could reasonably be provided by line or other methods of communication. Only a very limited number of frequency channels can be reserved for use within works sites of all kinds, and it is essential that each user should restrict the emission of radio energy to a minimum so that interference between services which may have to be allotted the same channel should be reduced as far as possible. This will be necessary especially in the iron and steel industry as there may be adjacent independent works sites in the same locality.

Figure 5 shows the position of the VHF band in the radio spectrum and gives details of the current international allocation of this band for all types of services. In the United Kingdom limited portions of the following frequency bands are available for private business use :

(*a*) 71·5–88·0 Mc./sec. (not continuous), channels are 50 kc./sec. wide

(*b*) 156–184 Mc./sec. (only a portion available for private services), channels are 100 kc./sec. wide

(*c*) 460–470 Mc./sec. (only a portion available for private services). This band comes within the UHF spectrum. Development of equipment has not yet reached the commercial production stage in this country.

It is probable that frequencies allotted by the G.P.O. for use in iron and steel works will initially be in the range 170–184 Mc./sec. When equipment is available, frequencies in the range 460–470 Mc./sec. may be allotted.

The G.P.O. also exercises control[18] over the frequency tolerance of the transmitter, the type of modulation, and the transmitter power, by means of a system of type-approval of equipment. Most of the principal manufacturers of radio communication

equipment have type-approved equipment available. It is understood that licences issued will contain a clause providing for their possible cessation in the event of an emergency.

PART III—REQUIREMENTS OF THE IRON AND STEEL INDUSTRY AND THE POSSIBILITIES OF MEETING THEM

Radio Coverage of a Works Site—Transmitter Power

The areas of works sites vary considerably, and the tonnage output is not a reliable guide to the area covered. For a large works, 4 square miles would represent the maximum likely to be covered, but in a works with mines the range might be as much as 10 miles. From Part II it will be apparent that satisfactory radio coverage over such distances should present little difficulty.

For the mobile station, where little space is available, the equipment must be as small as possible. The size is governed by the transmitter power which must be no larger than is necessary for adequate coverage. In battery-operated equipment, with no provision for charging at the mobile station, the power input must also be low.

Tests carried out in several works in this country have established that a transmitter power of 10 W. at the mobile station gives adequate coverage in most cases. It is felt that this figure could be reduced to 2–5 W., but further testing will be necessary before general recommendations of the minimum transmitter powers required for satisfactory service can be made. These tests should present no difficulty since there is already available in this country a 3-W. mobile transmitter, and others of similar power are being developed.

For the fixed-station equipment no severe limitations are imposed on the size and power consumption, the equipment being mains-operated. In addition, the location of the transmitter and hence the coverage area is fixed, so that possible interference with adjacent systems can be controlled. In these circumstances higher transmitter powers—10–25 W. would be permissible—can be used. However, to reduce the possibility of interference to other services, the power radiated should always be reduced as far as possible.

These considerations preclude the use of lightweight portable equipment of the ' walkie-talkie ' type, where the transmitter powers are less than 1 W.

Systems of Communication and Operating Procedure

The system of communication and operating procedure should be as simple as possible and should require no special training of the drivers. Sets should be equipped with pre-set controls and no dial-adjustments should be necessary. Modern VHF equipment satisfies these requirements.

Three systems of communication are possible between a fixed controlling station and a group of mobile stations : (1) Single-frequency simplex, (2) two-frequency simplex, and (3) duplex.

Single-Frequency Simplex—Fixed and mobile stations transmit and receive on the same frequency. One-way conversations only are possible, and the ' over-to-you ' technique, using a transmit/receive switch, is employed.

Table I

OPERATING SYSTEMS FOR VHF RADIO SUITABLE FOR USE IN THE IRON AND STEEL INDUSTRY

System and Procedure	Advantages	Disadvantages	Suitability for Selective Calling
SINGLE-FREQUENCY SIMPLEX*			
All stations transmit and receive on same frequency. Stations transmit and receive alternately, using ' over-to-you ' technique	Simple and cheap. All stations in range can intercommunicate	All stations can overhear. More liable to interference from and with adjacent installations. Departure from telephoning practice	Selective calling practicable from fixed to mobile station. Unwanted stations can interrupt
TWO-FREQUENCY SIMPLEX			
Fixed stations transmit on one frequency, mobile stations on the other. Stations transmit and receive alternately, using ' over-to-you ' technique	Simple and cheap. Partial privacy, unwanted stations hear only fixed station. Less liable to interference from and with adjacent installations than single-frequency simplex	Mobile stations can intercommunicate only through fixed station. Departure from telephoning practice	Selective calling practicable from fixed to mobile station. Unwanted stations can interrupt
DUPLEX			
Fixed stations transmit on one frequency, mobile stations on the other. Transmission and reception can proceed simultaneously	No ' over-to-you ' technique. Operation as with telephone	More costly. Two aerials usual at fixed and mobile stations, often difficult to locate aerials on loco. Power-supply demands are greater than simplex operation. Simplicity may lead to ' loose chatter,' reducing traffic capacity of system	Selective calling practicable from fixed to mobile station with full locking-out of unwanted stations

* Restricted to special cases by G.P.O. owing to liability to interfere with adjacent installations[10]

Two-Frequency Simplex—Two frequencies are used. The fixed station transmits on the one frequency to which all the mobile-station receivers are tuned, and the mobile stations transmit on the other frequency to which the fixed-station receiver is tuned. The 'over-to-you' technique is used.

Duplex—The fixed station transmits on the one frequency and the mobile stations on the other frequency, as with the two-frequency simplex. The equipment is arranged for simultaneous two-way conversations to proceed, as on the telephone.

Details of the three systems, together with their respective advantages and disadvantages, are summarized in Table I. Because single-frequency simplex is more liable to interfere with adjacent existing schemes, its use is now restricted by the G.P.O. to special cases. Thus the choice open to prospective users in the iron and steel industry lies normally between two-frequency simplex and duplex, neither of which allows mobile-to-mobile communication, other than through the fixed station. Mobile intercommunication with the fixed station acting as a repeater or relay station[20] is, however, a practical proposition for the iron and steel industry.

Voice and Indicator Calling—The simplest method of calling, *i.e.*, indicating an intention of transmitting a message, is voice-calling. The operator wishing to make a call merely transmits the name, number, or code word of the desired station. This voice-calling can be augmented or replaced at the mobile stations by some form of indicator, such as a bell or light, which is energized by the radiation of the unmodulated carrier from the fixed station. An indicator is desirable in two-frequency systems as it shows all mobile stations that the fixed station is engaged.

Selective Calling—In certain circumstances, for instance, when the volume of radio traffic is sufficiently heavy to be a nuisance to stations not directly concerned, or when secrecy is wanted, some form of selective calling, *i.e.*, the ability to call a particular station or group of stations without others overhearing, may be desired. Selective calling is applicable in varying degrees to the three systems of communication.

Several selective calling schemes are available, but basically they are of either the multi-tone or the impulsed single-tone type. A selective calling unit of the latter type, suitable for adding to a mobile transmitter/receiver, is shown in Fig. 20. With multi-tone selective calling, each station is allocated a particular tone to which a relay in its receiving aerial circuit has been tuned. With the impulsed single-tone type, each station responds to a series of impulses. Both systems can be extended to two or more digits if required.

Procedure is similar with both types and is as follows: radiation of the carrier from the station about to make a call locks out all the other stations in the system and energizes the engaged indicator, usually a lamp, at these stations, indicating that a call is about to be made. The called station is then freed by the dialling of the particular tone or series of impulses to which it is tuned, and a bell gives indication of the call. The engaged signal remains on at the unwanted stations during the conversation.

With single-frequency simplex and two-frequency simplex working, it is possible only to arrange for selective calling of the mobile stations by the fixed station, and it is possible to break in on a conversation between the fixed station and a particular mobile station. Selective calling is not practicable between mobile stations with these systems.

In duplex working, selective calling is possible between the fixed station and mobile stations, with full locking-out of unwanted stations. Selective calling between mobile stations with the fixed station operating as a manual or automatic exchange is not a practicable proposition.

As already mentioned, VHF installations should be kept as simple as possible, and it should be remembered that selective calling and lock-out features constitute an additional complication.

Audibility and Choice of Acoustic Equipment

Good quality reception is essential, as confidence in a radio traffic control system will very largely depend on it. High-level acoustic noises are a problem, but their effects can be reduced by providing the operators with telephone-type handsets, similar to the heavy-duty type in general use in works telephone systems. Figure 8 shows a typical handset with associated control unit.

The handset, however, is not suitable for use with voice-calling, which is the simplest method of operating an installation not incorporating some form of selective calling. In such cases a loudspeaker and a handset or hand microphone must be used. In view of the high ambient noise level in locomotive cabs an output of at least 2 W. from the mobile receiver will be required to drive the loudspeakers. Microphones should preferably be of the moving-coil type as cross-modulation is liable to occur with carbon microphones in high ambient noise levels. Figure 9 shows a combined loudspeaker and handset with a mobile transmitter/receiver, and Fig. 10 shows a hand microphone installed in a locomotive cab.

Although fixed microphones leave both the operator's hands free, they are somewhat difficult to operate satisfactorily in mobile stations, such as locomotives, since the driver must, when talking, occupy a certain position to bring his mouth close to the microphone.

At the fixed station, where conditions are less exacting, any desired arrangement of the above acoustic equipment may be made. Figure 11 shows a fixed-station installation with a loudspeaker built into the set and a fixed microphone.

Mobile Radio Equipment

Type of Set and Position of Mounting—Mobile VHF equipment for installation on works locomotives must be compact and suitable for mounting in such a position as to be readily accessible for maintenance purposes and yet not interfere with the working of the locomotive.

The principal trend in the design of modern mobile VHF radio equipment has been towards single-unit construction, in which the transmitter, receiver, and internal power supplies form a compact single unit mounted on a common chassis. A typical example is shown in Fig. 12.

The mounting of the set on the locomotive will depend largely on the size of the equipment and the space available. Having in mind the need for accessibility, the choice lies between mounting the equipment inside the cab, on top of the boiler of the locomotive, or on the running plates.

Equipment mounted inside the cab will have the advantage of being protected from the effects of the weather and extraneous heat when passing hot ingots, etc., and to a certain extent from the dust present in a works atmosphere. For diesel locomotives where the cabs are comparatively clean and spacious this would appear to be the best solution. If sufficiently compact, the sets can be mounted on brackets and suspended from the cab roof, as shown in Fig. 13, so as to leave the footplate clear and protect the sets from damage. In steam locomotives, the cabs are usually small, and if the set is to be mounted in the cab, the only possible position is under the roof. However, these cabs are often very hot and it may be necessary to mount the equipment externally, as shown in Fig. 6,[15] or on the running plates. Equipment mounted in this way will have the advantage of having a constant stream of air over it which will assist cooling. A disadvantage of outside mounting is that the locomotive may stop alongside a row of hot ingots or a furnace and the equipment will be exposed to excessive heat ; also, the equipment and the connections may be insufficiently protected from the weather and mechanical damage. The possibilities of avoiding these disadvantages are reviewed below.

Robustness of Sets—Present-day mobile VHF radio equipment has been designed chiefly for use in aircraft and pneumatic-tyred vehicles where operating conditions are not generally severe. Such equipment, however, is not sufficiently robust to withstand the far more exacting conditions in steelworks locomotives. Thus the equipment must be made to withstand the following conditions :

(*a*) Rough handling
(*b*) Shocks and vibrations due to shunting and bad track conditions
(*c*) Dusty and corrosive atmospheres and the effects of the weather
(*d*) High ambient temperatures.

Protection against rough handling may be achieved by enclosing the equipment in a robust metal casing. This casing may be either a permanent fitting on the locomotive, from which the set is removed for maintenance purposes, or an integral part of the set, depending on its size and weight.

The equipment may be rendered shock and vibration proof by mounting it on shock absorbers within the outer casing. This technique has reached an advanced stage as a result of Services' needs for which sets are required to be dropped by parachute.

Protection against dusty and corrosive atmospheres may be achieved by hermetic sealing of the box containing the set. Such measures, however, further aggravate the problem of dissipating the internal heat produced by the set. The volume of the box may be reduced if finning is used, and a dull black finish on the inner surfaces will assist heat absorption. With the higher-powered equipment, forced cooling, using fans and filters, may be necessary.

Equipment mounted in the cabs of steam locomotives will be required to operate reliably in an ambient temperature of about 40° C., but equipment mounted outside the cab may be subjected to considerably higher temperatures. This, however, should present no serious difficulty as all mobile VHF radio equipment is designed for possible use in the tropics. Tropicalization involves the use of special coatings and varnishes on components to prevent deterioration in conditions of excessive humidity and, in addition, resistors and valves are conservatively rated and all transformers are hermetically sealed.

Two manufacturers, working on these lines, have produced sets designed to overcome these difficulties ; one of these sets, consisting essentially of a motor-car set mounted on shock absorbers in a finned metal casing, is shown in Fig. 20.

All external wiring should be enclosed in suitable conduit.

Testing of Sets—In the absence of operating experience in iron and steel works, it is important that equipment should be tested by prolonged subjection to conditions resembling those existing in steelworks. At present, testing is left to the discretion of individual manufacturers, and the usual procedure is to apply the following typical tests to a sample of the output : (*a*) Bump test, (*b*) vibration test, and (*c*) temperature test.

In the bump test the set is mounted on a rigid table which is raised and dropped through distances of up to about 1 in. by cams driven by an electric motor. The set is subjected to this test continuously for about 5 min. to discover any constructional weaknesses.

Vibration testing is similar to the above, except that the table moves through distances of the order of 0·005 in., and the cams are driven over a wide range of speeds to detect resonances. The set is subjected to this test continuously for about 20 min.

In the temperature test the set is subjected to alternate cycles of heat and cold between temperature limits of − 40° C. and + 71° C. The set is mounted in a humidity cabinet and 100% humidity is introduced during the high-temperature cycles. It is tested continuously for a period of 6 days and is ' on ' during the whole test.

Aerials—Quarter-wave aerials, cut to the trans-

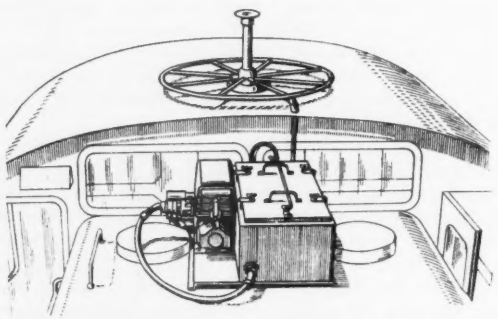

Fig. 6—Mobile transmitter/receiver mounted externally; aerial on cab roof (manufacturer D)

mitter frequency, are generally used at the mobile stations. These aerials must be vertically mounted in a flat ground plane and should have a clear field of view.

The best conditions will be obtained with a vertical aerial mounted on the roof of the cab, as shown in Figs. 6[15] and 7, but if the railway loading-gauge prohibits this, the aerial can be mounted over the boiler. With the latter arrangement, however, screening by the cab structure is possible. The installation shown in Fig. 6 includes a circular-shaped artificial ground plane. This device is necessary whenever the curvature of the existing ground plane is excessive, although that of the cab roof shown in this illustration would not appear to warrant the provision of an artificial ground plane.

VHF aerials are sometimes loaded, *i.e.*, inductances or capacitances are connected in series with them. This has the effect of broadening the tuning of the aerial and reducing its length. In this way aerials for use in the 180-Mc./sec. band can be reduced to about 9 in. long. Loading-gauge problems may be overcome by flexible aerials or horizontally mounted dipole aerials, as shown in Fig. 14. Horizontal mounting was adopted in this case because the length of aerial required for the frequency allocated (approximately 85 Mc./sec.) was too great for a vertical dipole. In this instance a horizontally mounted dipole aerial has provided adequate coverage, but in cases where maximum coverage is required, horizontal polarization is not recommended.

Fixed-Station Radio Equipment

No special requirements affect the choice of fixed-station radio equipment for installation in iron and steel works. Provided that the equipment is reasonably compact and readily accessible for maintenance purposes, existing fixed-station equipment is suitable.

Manufacturers producing the higher-powered mobile sets with transmitter powers of the order of 10 W. generally use mains-driven versions of these sets for the fixed stations. With the lower-powered mobile sets, a higher-powered fixed station transmitter is more usual. Figures 11 and 15 show typical fixed-station installations. By means of remote-control equipment the fixed-station transmitter/receiver can be operated over a single pair of telephone lines up to a distance of 5–10 miles ; alternative remote-control points can also be arranged.

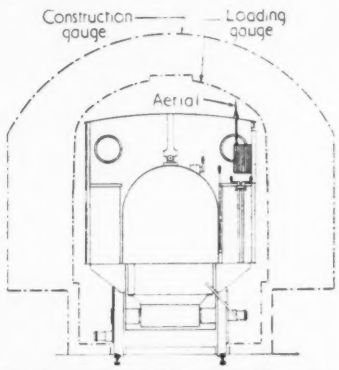

Fig. 7—Quarter-wave aerial mounted on cab roof (manufacturer B)

If necessary, the fixed-station equipment can be connected into a works private telephone system to allow messages from any point in the works to be radiated direct to the locomotives, although the G.P.O. will not permit the connection of radio equipment to any of their equipment other than private lines rented from them. Such an arrangement normally requires the radio to be operated on the duplex system, but satisfactory operation may be obtained with voice-operated relays in conjunction with two-frequency simplex. It is considered unlikely, however, that voice-switching would give completely reliable operation on works locomotives.

Fixed-station aerials are of the half-wave dipole type and are mounted in the same plane of polarization as the corresponding mobile aerials. The siting of the fixed-station aerial should be decided by the radio manufacturers, who may find it necessary to carry out signal-strength measurements in the area. It is, however, possible to house the transmitting and receiving equipment remote from the aerial or to mount the aerial considerably above it. Figure 16 shows a horizontally polarized fixed-station dipole aerial.

Power Supplies

Adequate power supplies, particularly in the case of the mobile sets, are of major importance, and will greatly influence the ease and cost of maintenance. Before considering possible methods of supplying power to the sets it is apposite to examine the power requirements of these sets.

Power Consumption of Sets—From Table II, described later, it is seen that typical power consumptions for sets of 10-W. transmitter power lie between 55 and 126 W. when standing-by, and rise to approximately 200 W. when transmitting. These figures are based on a 12-V. D.C. supply. Taking a figure of 100 W. for the average consumption over a 24-hr. period to represent normal steelworks operating practice, the daily energy demand of sets of 10-W. transmitter power will be of the order of 2·4 kWh. and approximately 200 amp.hr. of electricity will be required to meet this demand for 12-V. equipment.

Several manufacturers are developing sets of transmitter powers of 2–5 W. Information available indicates that the power consumptions of these sets will be of the order of 20 W. when standing-by and 60 W. when transmitting. In these circumstances the daily energy demand will be reduced to the order of 1 kWh., requiring approximately 80 amp.hr. of electricity.

There are four possible methods of supplying power to the mobile sets : (*a*) Primary batteries, (*b*) secondary batteries, (*c*) secondary batteries with *in situ* charging equipment, and (*d*) turbo-generators.

Primary batteries were used to a great extent during the war for mobile radio power supplies to Service equipment and are used today with ' walkie-talkie ' and other types of portable, light-weight VHF radio equipment. They are compact, easy to accommodate, and maintenance is simple. However, in view of the comparatively high power at present required to meet

Table II

PRINCIPAL FEATURES OF EXISTING VHF RADIO EQUIPMENT AVAILABLE FOR USE IN THE IRON AND STEEL INDUSTRY

(All equipment can be arranged for either simplex or duplex operation)

Set	Manufacturer	Fixed (F) or Mobile (M)	Fig. No.	Modulation	Transmitter		Receiver		Power Supplies, V.	Power Consumption, based on (12-V., D.C.), W.			No. of Units in T/R	Dimensions, in.			Wt., lb.
					Power at 180 Mc./sec., W.	Deviation (kc./s.) or Modulation (%)	Audio Output, W.	Sensitivity, mV.		R only	R and T Heaters	R and T		Width	Height	Depth	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1*	A	M	20	FM	10	±12·5 kc./s.	1	<0·5	6 or 12 V. D.C. or 24 V. $\widetilde{500/750}$ A.C.	55	95	175	1	33	16	18	224
2*	A	M	20	AM	10	95%	1	0·5	6 or 12 V. D.C. or 24 V. $\widetilde{500/750}$ A.C.	48	78	192	1	33	16	18	224
3†	B	M	17, 18	FM	10††	±15·0 kc./s.	1	2·6††	6, 12, or 24 V. D.C.	60	Not specified	210	2	T 8 R 8	T 7½ R 7½	T 15½ R 15½	T 15½ R 15½
4†	B	M	17, 18	AM	10††	90 to 95%	1	2·6††	6, 12, or 24 V. D.C.	60	Not specified	210	2	T 8 R 8	T 7½ R 7½	T 15½ R 15½	T 15½ R 15½
5	C	M	23	AM	12	100%	1	1·0	6 or 12 V. D.C.	48	65	150	2	17‡‡	14‡‡	8‡‡	Combined weight 40
6‡	C	F	22	AM	12	100%	3	0·5	200/250 V. $\widetilde{50}$ A.C.	100	Not specified	200	1	24	24	12	90
7	C	M	9	AM	3	100%	1	1·0	6 or 12 V. D.C.	Not specified	65	86	1	13	10¼	7	15
8§	D	M	19	FM	10	±15·0 kc./s.	6	0·5	6, 12, or 24 V. D.C. or 24 V. $\widetilde{500/750}$ A.C.	126	Not specified	204	1	14	12	24	100
9‖	E	M	21	FM	12††	±15·0 kc./s.	2½	<0·5	6 or 12 V. D.C.	85	105	165	2	T 14 R 11¾	T 5¾ R 5¾	T 12½ R 12½	T 28 R 19
10**	E	F	..	FM	12††	±15·0 kc./s.	2½	<0·5	200/250 V. $\widetilde{50}$ A.C.	120	Not specified	230	2	T 15 R 11¾	T 5¾ R 5¾	T 12½ R 12½	Combined weight 49

* Modified for use on works locomotives. Mains-operated, without protective casing, for fixed station.
† Mains-operated version available for fixed station.
‡ For use with set No. 5.
§ Specially designed for locomotives. Power amplifier unit is added for fixed station, increasing transmitter power to 25 W. All valves are directly heated.
‖ The two units can be mounted on a single fitting.
** For use with set No. 9.
†† Estimated figures.
‡‡ Overall dimensions.
T = transmitter, R = receiver.

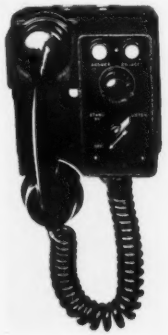

Fig. 8—Telephone-type hand set and control unit (manufacturer A)

Fig. 9—Mobile transmitter/receiver with hand set and loudspeaker (manufacturer C)

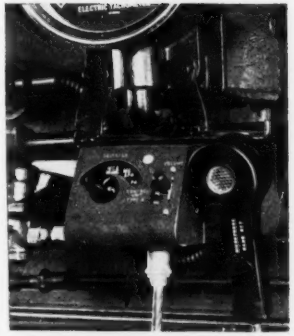

Fig. 10—Hand microphone and control unit (manufacturer C)

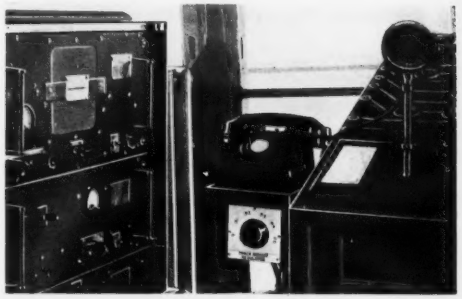

Fig. 11—Fixed transmitter/receiver with fixed microphone (manufacturer C)

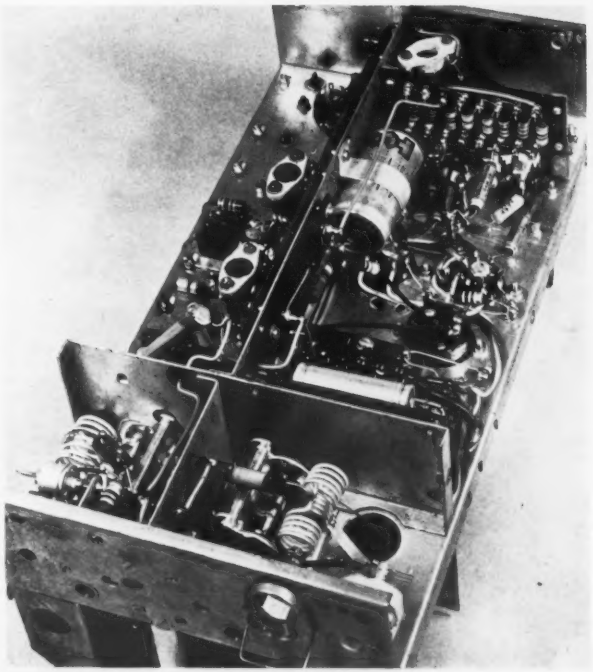

Fig. 12—Mobile transmitter/receiver. Internal view showing single-unit construction (manufacturer E)

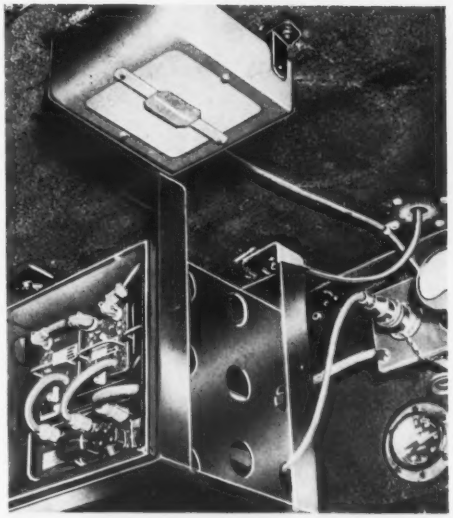

Fig. 13—Mobile transmitter/receiver with loudspeaker fixed inside locomotive cab roof (manufacturer C)

Fig. 14—Horizontally polarized aerial

Fig. 15—Fixed transmitter/receiver with hand microphone (manufacturer B)

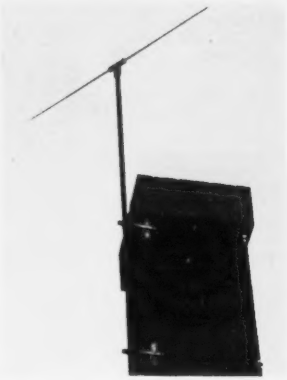

Fig. 16—Horizontally polarized dipole aerial

Fig. 17—Mobile transmitter (manufacturer B)

Fig. 18—Mobile receiver (manufacturer B)

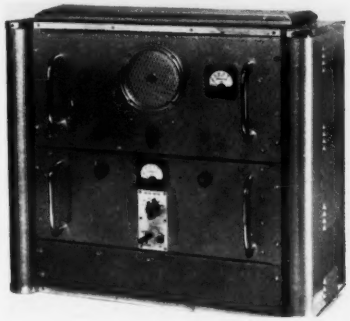

Fig. 22—Fixed transmitter/receiver (manufacturer C)

Fig. 19—Mobile transmitter/receiver (manufacturer D)

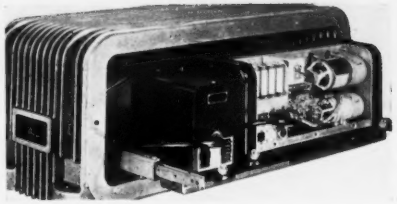

Fig. 20—Mobile transmitter/receiver, showing finning and selective calling unit (manufacturer A)

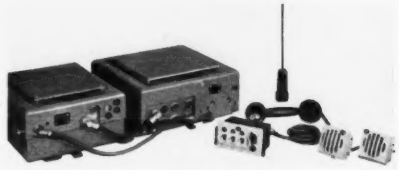

Fig. 21—Mobile transmitter/receiver (manufacturer E)

Fig. 23—Mobile transmitter/receiver (manufacturer C)

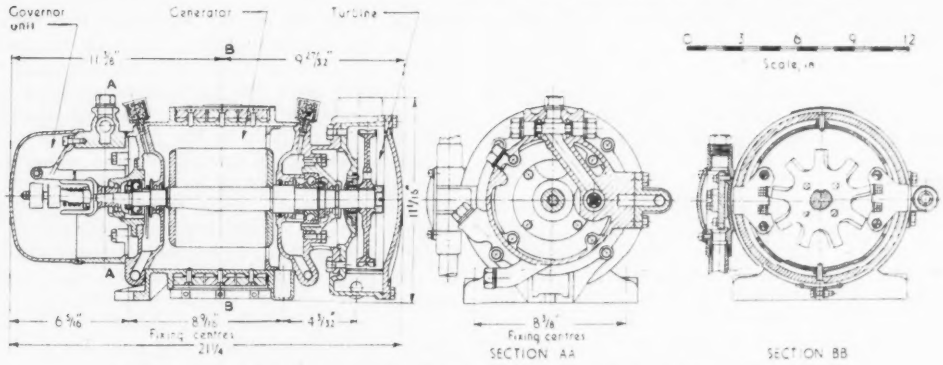

Fig. 24—General arrangement of steam turbo-generator set (manufacturer F)

the needs of the iron and steel industry for traffic communications, they are not suitable. Future reductions in transmitter powers may permit the use of this type of battery.

Secondary batteries are comparatively simple to instal on a locomotive and can be changed without undue trouble. To be reasonably portable, however, the batteries would have to be limited in capacity to about 100 amp.hr., which, with 10-W. sets would involve changing the batteries each shift. This would greatly increase charging commitments and the increased wear and tear would reduce the life of the batteries. With steam locomotives, heat would also have deleterious effects.

Mechanical damage to batteries during constant changing for charging purposes might be reduced by the use of alkaline batteries, while spillage of electrolyte has been avoided in some portable sets by the so-called dry accumulator. However, secondary batteries would require some kind of *in situ* charging equipment.

Secondary batteries with *in situ* charging equipment are in use for mobile radio supplies on nearly all existing VHF equipment. Diesel locomotives are equipped with an engine-driven generator for charging the starter batteries and this system can also supply the radio equipment by tapping direct across a 6- or 12-V. section of the starter battery, or preferably by producing the desired D.C. voltage by connecting a dynamotor across the whole battery. Maintenance consists simply of periodical inspection and ' topping-up ' the cells with distilled water.

With steam locomotives the only suitable charging device is the turbo-generator.

Turbo-generators are used in this country for locomotive cab and instrument lighting on main-line railways and abroad for power supplies to the locomotive head and rear lamps. In this country a small unit is manufactured which has an output of either 350 or 500 W. at a nominal 24 or 32 V. and 500–750 cycles/sec. This unit has great possibilities for mobile radio supplies on steam locomotives because it is very compact, maintenance is confined to weekly ' topping-up ' of two oil wells, and dismantling is required only when the locomotive is being overhauled. Several of these units have been supplied to iron and steel works in this country for such purposes as steam crane lighting.

The initial installation of the turbo-generator involves mounting the unit on the locomotive and providing a steam supply. Figure 24 shows a general arrangement of the unit, and positions recommended for mounting the unit on the locomotive are shown in Fig. 25.

The turbine is of the impulse type, rotating at about 4000 r.p.m. The rotor, consisting of a single disc carrying one row of impulse buckets, is machined from solid bronze, thus eliminating any possibility of loose blades and ensuring that balance is maintained. The single nozzle has an extension carrying a number of fixed redirecting vanes covering a portion of the periphery of the rotor ; these vanes redirect the steam into the buckets and ensure that full advantage is taken of the kinetic energy of the steam.

The turbine casing and housings are made of close-grained cast iron and are cast integrally in a labyrinth passage for the exhaust steam, to reduce exhaust noise to a minimum.

The governor is situated at the remote end of the shaft where it is not exposed to high temperature or corrosion and is readily accessible. The steam valve, which gives close speed regulation, is so designed that any wear in the governor motion parts will cause a decrease in speed and any failure will shut off the steam.

The inductor alternator has stationary armature windings and field magnets, and the only rotating part is a laminated soft-iron toothed inductor. The

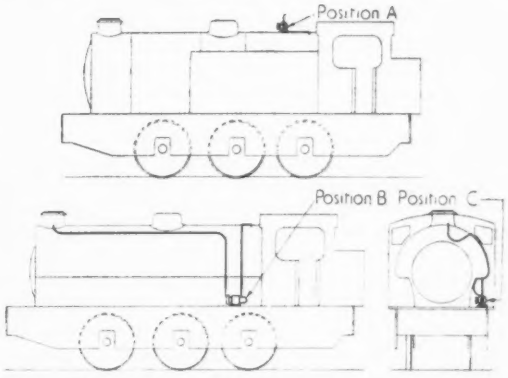

Fig. 25—Mounting positions of steam turbo-generator set (manufacturer F)

alternator rotor shaft is of high-grade steel and is extended at one end to carry the turbine wheel and at the other end the governor. Two ball-bearings carry the whole rotating unit and they are mounted in the central alternator housing. The bearings are lubricated by oil rings dipping into wells of large capacity. No other points on the machine require lubrication.

With the smallest unit available, which would be ample for the requirements envisaged, an output of 350 W. can be maintained at steam pressures of 75–250 lb./sq. in. A special nozzle will give 350 W. output down to pressures of about 50 lb./sq. in., but the overall efficiency of the turbine is reduced.

Steam consumption at a steam pressure of 170 lb./sq. in. varies from 35 lb./hr. at no load to 85 lb./hr. at 350 W. The voltage regulation of the alternator is good and is shown in Fig. 26.

The turbo-generator may be used either to charge secondary batteries, possibly intermittently, or to provide continuous direct-on supplies to the mobile sets. The latter arrangement is preferred by radio manufacturers as it enables them to replace the battery-operated vibrators and dynamotors by more

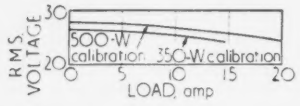

Fig. 26—Regulation curve of steam turbo-generator (manufacturer F)

robust and reliable transformers and rectifiers for internal power supplies. In addition, the high frequency of supply greatly simplifies smoothing and reduces the size of circuit components.

In view of the excess power generated by the turbo-generator, an electric headlight on the locomotive might be considered. This would be of value when operating at night and in fog.

Fixed-station power supplies are derived from the 200/250-V., 50-cycles/sec., single-phase, A.C. mains. As works power supplies fluctuate considerably, voltage stabilization may be required.

Maintenance

Ease and low cost of maintenance are essential for all VHF radio equipment for use in the iron and steel industry. The maintenance of this equipment is work for the specialist radio mechanic and, in most cases, is beyond the capabilities of electrical maintenance personnel. Certain radio manufacturers will train works personnel in maintenance of the equipment. The alternative is for the steelworks to carry a comprehensive stock of spare sets or units and to return faulty equipment to the manufacturer for repair under a maintenance contract. Some radio manufacturers are setting up depots where skilled men and the necessary testing gear will be available.

PART IV—SYSTEM OF MODULATION

The two systems of modulation in use for transmitting intelligence at very high frequencies are frequency modulation (FM) and amplitude modulation (AM). In FM the frequency of the carrier wave is made to vary in sympathy with the modulating voltage produced by the action of the voice on a microphone, the amplitude remaining constant. In AM the amplitude of the carrier wave is made to vary in sympathy with the modulating voltage, the frequency remaining constant. The two systems are illustrated graphically in Fig. 27.[23]

Before installing a system of radio communication in a steelworks it must be decided whether FM or AM is to be used. Much has been written on this subject, but a comprehensive comparison of the relative merits of the two systems is beyond the scope of the present paper. However, certain relevant information is briefly discussed below.

The rapid growth in importance of FM for VHF radio communication over the past decade has been due largely to the fact that a better signal/noise ratio is possible with FM than with the older-established AM. This improvement is definitely obtained,[24] but a quantitative measure of its effect under a given set of conditions is not possible without comprehensive site tests of the two systems. In general, such tests are impracticable, but, more important, the question is not a vital one in a steelworks since the improvement with FM appears as better reception at the extreme limits of the range and, in general, the required steelworks coverage will be well within these limits.

A disadvantage of FM is that it is generally necessary to control the mean carrier frequency to within appreciably finer limits than is possible with ordinary commercial crystals,[17] and this usually means that the crystal of an FM transmitter must be temperature-controlled, involving increased initial cost and power consumption and, although no operating experience under steelworks conditions is available, probably more maintenance. One manufacturer claims that temperature control of crystals in FM transmitters and receivers is not necessary, but in any case any increased expense would be largely offset by the fact that low-level modulation can be employed with FM.

Perfect automatic gain control is inherently possible

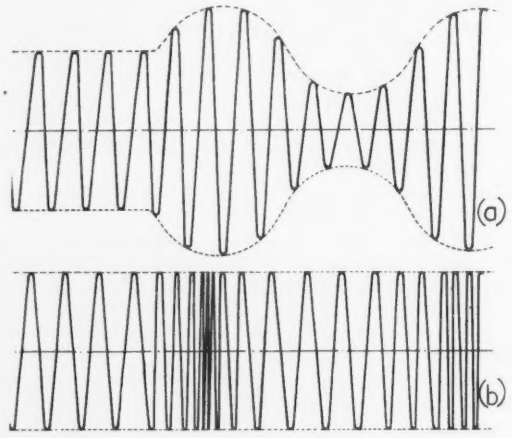

Fig. 27—Diagrammatic comparison of (*a*) amplitude modulation (AM) and (*b*) frequency modulation (FM). (*a*) Intelligence transmitted by amplitude-modulated wave ; (*b*) the same intelligence transmitted by frequency-modulated wave

with FM, but it is claimed that manufacturers of AM have developed automatic gain control to give comparable performance.

The advantage of FM of requiring less D.C. input to the transmitter than AM, for a given output, is of little practical significance in low-power mobile VHF installations of the type under consideration. Similarly, the advantage of AM, which permits easier simultaneous operation of more than one fixed transmitter to increase the coverage of a particular frequency, is not important over the relatively small areas envisaged.[17]

In the absence of operating experience in the iron and steel industry it would thus appear that there is no evidence that either AM or FM offers outstanding advantages for use in steelworks.

PART V—SOME DETAILS OF PRESENT-DAY VHF RADIO EQUIPMENT

Technical Details

Table II summarizes the more important features of existing VHF radio equipment which, with modifications in most cases, would be suitable for use in steelworks locomotives. Examples of the equipment are illustrated in Figs. 17–23. All equipment listed in Table II is available for either simplex or duplex operation. In column (3) is given the duty for which the equipment is intended, *i.e.*, for mobile or fixed stations; it will be noted that the equipment is supplied for both in most cases, that for fixed stations being designed for power supplies from the standard A.C. mains. Where this is not the case, details of the fixed-station equipment for use with a particular equipment are included in the table.

Column (6) gives details of the transmitter power output at 180 Mc./sec. It is necessary to specify a particular frequency when referring to this figure as most of the equipment shown in Table II is available for operation over the entire VHF band up to 185 Mc./sec., and the power output of the radio frequency power amplifier valve in a transmitter is reduced as the higher frequencies are approached.[25]

Column (7) gives the deviation in the case of FM equipment or percentage modulation in the case of AM equipment. These terms are defined as follows :

Deviation—The variation in carrier frequency away from the mean carrier frequency in FM transmitters (generally expressed in kilocycles per second)

Percentage Modulation (*Degree of Modulation*)—The ratio of the average envelope amplitude less the minimum envelope amplitude to the average envelope amplitude in AM transmitters.

As shown in Part II, the maximum permissible deviation in the 180-Mc./sec. band is $\pm$ 50 kc./sec., but to ensure that there is no interference with users on adjacent channels, the deviation is kept to much lower limits in practice.

When the percentage modulation is 100, the amplitude variations carry the envelope amplitude to zero during the troughs of the modulation cycle and the modulation is complete, *i.e.*, the envelope is varied through the maximum range that is possible without distortion.

In column (8) is given the audio output power of the receiver. This represents the maximum power available from the receiver for driving the loudspeaker or handset and is usually measured with the receiver set for maximum sensitivity.

The sensitivity of the receiver is given in column (9). Sensitivity is defined as the voltage which must be induced in the aerial by a radio signal to give an output from the receiver above the ' threshold ' value, generally taken as 50 mW. It is measured under conditions of maximum volume.

From a knowledge of transmitter power and receiver sensitivity an idea of the behaviour of the equipment at various ranges can be obtained.

Columns (11), (12), and (13) give details of the power consumption of the sets under various conditions. The figures in the case of the mobile sets are based on a 12-V., D.C. supply, and in the case of the fixed-station equipment on a 200/250-V., single-phase, 50-cycle supply. Column (11) gives the power consumption of the receiver only, and column (12) that of the receiver together with the transmitter valve heaters. With this power consumption the set is generally referred to as in the standby condition, as it is ready for immediate acknowledgment of a message. Some sets are designed for standing-by with the receiver only switched on and the transmitter must warm up for at least 30 sec. before a reply can be made. A newly developed directly heated transmitter power-amplifier-valve is being used in set No. 8, which reduces this delay to about 3 sec.

Column (13) gives the power consumption under transmitting conditions with both transmitter and receiver fully operative.

Columns (15), (16), (17), and (18) give overall dimensions and weights of the equipment. Only set No. 8 of those shown in Table II has been specially designed for use on locomotives, although Nos. 1 and 2 are modified so as to be more suitable for steelworks use. The average dimensions and weight of the others shown do not, therefore, include the robust hermetically sealed casing which will be required for such a purpose.

Approximate Costs

The cost of a fixed-station installation consisting of a transmitter/receiver, control unit, loudspeaker, handset or microphone, aerial and feeder, at present is £160–200. A mobile-station installation without protection would cost £100–200, depending upon the transmitter power, but mechanical protection, selective calling, and provision of a turbo-generator would constitute further appreciable expense. Inclusive of these items the cost is likely to be £200–400.

CONCLUSIONS

(1) Low-power mobile VHF radio communication between works locomotives and one or more control points would increase locomotive availability, provide better facilities for handling emergencies, reduce shunting, and allow more efficient working, especially at night and in fog (p. 428).

(2) The G.P.O. ' business radio ' scheme provides for low-power mobile VHF radio communication in this country, and it is already in use in other industries. Licences issued will, it is understood, contain a clause providing for their possible cessation in the event of an emergency arising (p. 429).

(3) Tests by manufacturers of VHF radio equipment indicate that adequate radio coverage of iron and steel works sites in this country is possible using transmitters of 10-W. power with a single fixed-station transmitting aerial mounted at a height of some 30 ft. (p. 430).

(4) A reduction of transmitter powers to the order of 2–5 W. may be possible, but more evidence is required before a firm recommendation can be made. Smaller sets and lower power consumptions would follow (p. 430).

(5) Radio set operation and operating procedure are simple and no special training of personnel is required (p. 430).

(6) The choice of system lies between two-frequency simplex, and duplex. Selective calling of the mobile stations by the fixed station is possible with both systems, but full locking-out of unwanted stations can be incorporated only in duplex. Selective calling and lock-out features constitute an additional technical complication (p. 430).

(7) A wide range of acoustic equipment exists, and several combinations of handset, loudspeaker, and microphone are possible. At mobile stations the handset is the most effective in reducing the effect of high ambient noise (p. 431).

(8) Some mobile VHF radio equipment is not sufficiently robust to withstand the onerous conditions in iron and steel works, but two manufacturers have overcome this by mounting equipment on shock absorbers within hermetically sealed, robust metal castings (p. 432).

(9) At present mechanical testing of VHF radio equipment is carried out by radio manufacturers. A standard mechanical test schedule, representative of conditions in iron and steel works, should be established (p. 432).

(10) Mobile equipment is not easily accommodated on steelworks locomotives and should therefore be reduced in bulk as much as possible. Probably the best arrangement is to mount the sets high up in the cab with controls at hand level (p. 431).

(11) Existing fixed-station equipment is quite suitable for use in iron and steel works. Remote control of the fixed station transmitter/receiver can be arranged (p. 433).

(12) Mobile power supplies are a major problem on works locomotives. In diesel locomotives the starter batteries and *in situ* charging equipment are a suitable source of power. In steam locomotives, batteries without *in situ* charging equipment are impracticable. The turbo-generator used for locomotive lighting is a suitable power unit (p. 433).

(13) There is no evidence that either AM or FM offers outstanding advantages for steelworks working (p. 436).

(14) Basic costs are likely to be £160–200 for a fixed station and £100–200 for a mobile station (p. 437).

Acknowledgments

The authors would like to express their appreciation for the co-operation so cordially given to them, in preparing this report, by the manufacturers of radio and turbo-generator equipment, the Railway Executive, the G.P.O. Engineering Department (Radio Branch), the British Broadcasting Corporation, and a number of iron and steel companies.

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A Proposed Method of Specifying Travel-Motion Performance for Steelworks Overhead Cranes

By D. A. Wise, B.Sc., and L. N. Bramley, Ph.D., M.Sc.(Eng.), A.M.I.E.E.

SYNOPSIS

An attempt has been made to provide an alternative method of specifying travel-motion performance, as the present method, the specification of geared speeds, is considered to be inadequate.

An analysis has been made of the performance characteristics of 68 travel motions. From this analysis a method of assessing travel-motion performance has been evolved to take into account both the initial acceleration and the speed of the motions. As a result, the long-travel motions have been grouped into five performance classes, and the cross-travel motions into three performance classes. This classification should enable the purchaser to classify his own cranes and to order new ones to the performance standard he requires. The standardization of performance achieved by this classification should also assist the crane makers.

It is intended that this new method should be used only when the purchaser is unable to formulate a duty cycle for a crane, since it is generally agreed that the latter is the best method by which a purchaser can specify performance requirements, but it is not possible for the majority of steelworks cranes.

In formulating the new method it was considered to be basically important that the purchaser should give a pure performance specification to the crane maker, and also that the method should lend itself to simple acceptance tests. The quantitative classification described has been included also in the B.I.S.R.A. specification for heavy-duty cranes, which is shortly to be issued.

Introduction

ELECTRIC overhead travelling cranes have been in use for over 40 years, and although until recent years travel-motion performance has been specified only in terms of speed, it has been recognized for some time, notably by West,[1] that acceleration also is important. The 1949 edition of the American Crane Specification[2] has taken account of this fact by allowing the purchaser to specify the travel-motion accelerations quantitatively. The difficulties in specifying acceleration in a practical way are considerable, however, and this paper examines these difficulties and suggests a possible solution.

This paper deals only with heavy-duty steelworks cranes having a D.C. power supply. It should be emphasized that the term ' heavy duty ' refers to the continuous and arduous nature of the duty required from most steelworks cranes, and is not connected with their actual weight or the loads they carry. Ground chargers should not rightly be under the heading of overhead cranes, but they have been included in this investigation since their travel motions are similar.

Some difficulties were encountered during the investigation (*e.g.*, it was not possible to carry out extensive tests on loaded cranes), and the limitations thereby imposed on the results have had to be carefully considered.

Performance Specification according to Duty Cycle

Formulation of a duty cycle is generally considered to be the most satisfactory method by which the purchaser can inform the crane maker of crane performance requirements. In this instance ' duty cycle ' does not mean only one complete cycle of operation of a crane, but covers a period of time during which the individual cycle is continually carried out. With this ideal method of specification the crane maker is free to settle design details of the crane, such as gear ratio, size of motor, and type of control gear, so that the duty cycle is complied with. Full provision is made in the B.I.S.R.A. specification[3] for the purchaser to order a crane on a basis of the duty cycle in cases where sufficient details of this are known.

It has not been found possible within the industry to formulate a duty cycle for the majority of steelworks cranes, although in the opinion of the authors some progress is possible along these lines. The discussion of this aspect lies beyond the scope of the present paper.

Disadvantages of Present Methods for Specifying Performance

The present tendency in specifying travel-motion performance is for the purchaser to specify a geared speed for each motion ; geared speed being defined as the speed of a motion when its driving motor is operating under full load, as given on the nameplate. This method has the advantage that it affords a simple means of ' pegging ' the travel-motion performance of a crane, and consequently it has become common practice within the industry to consider travel-motion performance in terms of geared speed. This method is unsatisfactory, for the following reasons :

(*a*) It is possible to gain only a rudimentary conception of travel-motion performance from a knowledge of geared speed or in fact of any one speed, since most crane motions are driven by series motors and thus

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Dr. Bramley and Mr. Wise are members of the Electrical Engineering Section of the Plant Engineering Division of the Research Association.

are variable-speed machines with a useful performance over a wide range of speeds

(*b*) Acceleration is important in assessing travel-motion performance, and geared speed takes no account of this. Thus if a crane is bought with a travel motion having a geared speed equal to that of a similar one already existing, there is no certainty that the motion of the new crane will duplicate the performance of the earlier one.

The disadvantages of the present situation are two-fold. In the first place the purchaser has no means of giving an adequate definition of the performance he requires from a crane, and in the second place the crane maker is not in the best position to produce the required crane, since its required performance is not fully known to him. In some cases the consequence has been that only after the erection of a crane has it become apparent that modification to a drive would be needed to make the crane perform satisfactorily. Occasionally, a compromise improvement only has proved possible, and efficiency has thereby been permanently impaired.

Cases are known where design details, such as gear ratio, size of motor, and type of control gear for crane motors, are given by the purchaser. This is not considered to be good practice, for if the crane maker is supplied with adequate information on the required crane performance he should be able to settle these details to the best advantage.

The foregoing remarks are not intended to suggest that geared speed should be ignored in the design of travel motions, but are intended to show that it is insufficient to take this as the sole criterion of performance.

Basic Considerations for the Proposed Method of Specifying Performance

The situation so far outlined gives rise to the need for a new and improved method for specifying crane travel-motion performance when, as is mostly the case, the duty cycle of the crane is unknown or unpredictable. As already indicated, this method should take account of both speed and acceleration of the crane motions.

West[1] was apparently the first to perceive that it was necessary to classify cranes according to the performance required of them, and he gives the following general classification of steelworks cranes, based on consideration of both speed and acceleration of the long-travel motions :

"*Class* 1—Good acceleration and braking, short average trips, high top speed unnecessary

Class 2—Reasonable acceleration and braking, frequently fairly long trips, and high top speed therefore often required

Class 3—Acceleration not important, smooth braking, length of trip very variable, long-travel speed not important, accurate load spotting."

To ascertain whether travel motions could be logically classified according to a system based on performance considerations, the performance characteristics of 68 crane motions were measured. The curves obtained were examined in the light of West's classification and it was found that this formed a convenient nucleus around which to evolve a more comprehensive system of classification.

In formulating the new method the following tenets were considered to be basically important :

(*a*) The purchaser should specify only performance to the crane maker, leaving the crane maker free to design the crane and settle such design details as gear ratio, size of motor, and type of control gear for each transmission

(*b*) The method of specification should be such that simple tests can be carried out after the erection of the crane to ascertain whether or not it complies with the specification.

Before describing the proposed method of performance classification, it is necessary to study in some detail the form of travel-motion performance curves.

FORM OF PERFORMANCE CURVES

Form of Speed/Time Curve

The form of the complete speed/time curve (not drawn to any particular scale) for a travel motion is given by *OABCDE* in Fig. 1. This curve can be divided into five parts as follows :

(*a*) *OA* represents the initial acceleration of the motion up to the time when all controlling resistance has been cut out of the motor circuit. This part of the curve is ideally straight

(*b*) *AB* represents further acceleration of the motion, with full line voltage across the motor, up to the balancing speed ; balancing speed being defined as the top speed reached by a motion when given sufficient distance for it to be attained

(*c*) *BC* represents travel of the motion at its balancing speed

(*d*) *CD* represents coasting of the motion with no power applied to the driving motor and no brakes applied

(*e*) *DE* represents braking of the motion to a standstill.

In practice, the balancing speed of a motion is seldom attained, and extensive coasting is rarely used. Thus a more accurate picture of the speed/time curve for normal working conditions is given by *OAB′C′* in Fig. 1.

Form of Distance/Time Curve

Oabc in Fig. 2 shows the form of the complete travel-motion distance/time curve. This curve can readily be obtained from the speed/time curve by graphical integration, and its relationship in form to its corresponding speed/time curve is shown in Fig. 2. The curves show :

(*a*) *OA* and *Oa* : Initial acceleration while resistance is being cut out of circuit

(*b*) *AB′* and *ab* : Acceleration with full line voltage across motor

(*c*) *B′C′* and *bc* : Braking to a standstill.

NATURE OF THE PROBLEM AND METHOD OF APPROACH

The problem of specifying crane performance consists of finding a method by which the performance characteristics of the crane motions can be compared. Ideally this entails the study of the whole of the performance curve, and any 'foreshortened' version of it, for each of the crane motions and for each different load condition under which the crane would be required to work.

This would have been a formidable task and one outside the resources available, and it has therefore been necessary to simplify the issue. The simplifications that have been made, and justification of them as far as possible, are as follows :

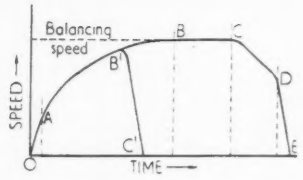


Fig. 1

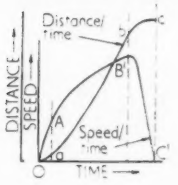


Fig. 2

Fig. 1—Form of speed/time curve for a travel motion
Fig. 2—Form of distance/time and speed/time curves for a travel motion

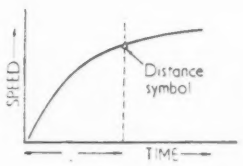


Fig. 3

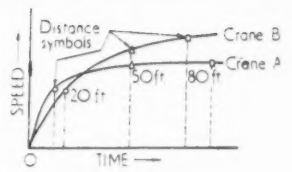


Fig. 4

Fig. 3—Distance-symbol convention
Fig. 4—Use of distance-symbol convention

(*a*) The problems of hoist-motion performance are radically different from those encountered with travel motions, and the existing method of specifying weights to be lifted and speeds to be attained by hoists is considered adequate. Special motions, such as the slewing motions of charging machines, need separate treatment. For these reasons travel motions only have been considered.

(*b*) The long-travel and cross-travel crane motions present different problems because of the trip distances involved. The trip distance of a cross-travel motion is limited by the span of the crane, whilst the trip distance of a long-travel motion depends on the crane duty and the size of the shop, and can vary within wide limits. The net effect is that the crab is often moved into position during transit of the crane along the gantry and thus, in most cases, the cross-travel does not limit the performance of the crane. For this reason cross-travel motions have not been dealt with in such detail as long-travel motions.

(*c*) One possible method of performance comparison, and probably the best from a technical point of view, is to time the motions over a number of fixed distances, starting and finishing at rest, and to compare the resulting characteristics. This method has the merit that it takes into account the acceleration, speed, and deceleration of the motion, but it has the disadvantage that arrival at the characteristic required for the comparison (*viz.*, trip distance against a base of total time) involves a lengthy testing technique which is not likely to find favour in steelworks.

It is a considerable simplification to compare motions, not on a basis of the trip-distance total-trip-time characteristic, but on a basis of speed/time which, in contrast, is quite simply obtained. This is justifiable since the efficiency of braking on modern cranes is in little doubt, so that this part of the speed/time curve is not so important as the initial accelerating period. Also, since deceleration is generally greater than acceleration, it represents only a small portion of the characteristic curve.

For these reasons travel motions of cranes have been compared on that part of the speed/time curve delineated in Fig. 1 by OAB' where B' is some point below the balancing speed. This takes account of both initial acceleration and what might be termed operating speed.

(*d*) There is no doubt that the characteristic performance of a motion should include some consideration of the load it carries. Unfortunately, it was not found possible, from a production point of view, to make tests on loaded motions except in two instances; and the authors were faced with the alternatives of testing unloaded motions or none. It was considered that such tests would still be valuable, and subsequent study of the results obtained has confirmed this view. The arguments for the usefulness of unloaded testing may be stated as follows:

(i) Cranes operate unloaded for at least half of their running distance and thus, for all but the heaviest cranes, for a similar proportion of their running time. Even when loaded they are not always fully laden, so that it appears likely that the average load carried by a crane will be less than half of the full load

(ii) Most steelworks cranes are rated to carry loads of less than 20 tons, and in the majority of cases the rated load amounts to less than $\frac{1}{4}$ of the unladen weight of the crane. This may be confirmed by reference to Table I, which gives details of rated loads and unladen weights of the tested cranes. Similar considerations also apply to the cross-travel motions of moving-cab cranes (Table II)

(iii) An increase in weight by loading does not result in a proportional decrease in the balancing speed of the motion owing to the shape of the speed/torque characteristic of the series motor.

From this reasoning it may be stated that the speed/time curve for the majority of unloaded long-travel motions bears a fair relation to that of the motion with average loading, and that errors involved in using them quantitatively in studying performance will not be excessive.

These conclusions do not apply to ladle-crane motions and cross-travel motions of fixed-cab cranes. In these cases the speed/time curves of the unloaded travel motions cannot be used quantitatively as measures of performance. It is claimed, however, that in the absence of quantitative data, they do supply some sort of qualitative guidance.

On these tenets a system of classification has been devised which is simple and appears to be workable. In the case of long-travel motions, classification is achieved by comparing (*a*) the initial accelerations characterized by the initial slopes of the speed/time curves, and (*b*) the speeds attained after some convenient time interval from rest. In the case of the cross-travel motions both initial accelerations and speeds are implicitly accounted for by the comparison of the times taken for the motions to reach a fixed distance from rest.

A practical advantage of the proposed new method

Table I

CLASSIFICATION OF LONG-TRAVEL MOTIONS

Reference	Crane Duty	Steelworks*	Crane Maker*	Load, tons	Unladen Weight, tons	Unladen wt. / Laden wt.	Rated Motor H.P.	Power/Weight Ratio, h.p./ton		Rated Motor Speed, r.p.m.	Gear Ratio	Dia. of Road Wheel, ft.	Revolutions of Motor for 1 ft. Motion of Crane	Geared Speed, ft./min.	Time to Move 8 ft. from rest sec.	Acceleration Class	Speed after 10 sec. from rest, ft./min.	Speed Class	General Class
								Laden	Unladen										
1	General purpose	D_2	N	10	47	0·82	70	1·23	1·49	520	1 : 13·9	3·0	1·47	352	2·5	High	528	High	
2	Magnet	F	N	20	36	0·64	47	0·84	1·31	600	1 : 12·4	2·25	1·76	342	2·5	High	435	High	1
3	Billet handling	C	C	15	30	0·67	40	0·89	1·33	600	1 : 9·4	2·0	1·50	401	2·7	High	546	High	
4	Ground charger	E	N	33 cwt.	†	..	25	..	..	570	1 : 7·8	1·75	1·42	402	2·35	High	396	Medium	
5	General purpose	F	N	5	38	0·88	20	0·47	0·53	650	1 : 11·4	2·0	1·81	358	2·35	High	366	Medium	
6	Billet handling	F	..	10	24	0·71	25	0·73	1·04	575	1 : 18·05	3·0	1·92	300	2·75	High	381	Medium	2
7	Soaking-pit charger	C	F	4	57	0·94	50	0·82	0·88	600	1 : 13·1	2·5	1·67	360	2·8	High	417	Medium	
8	Stock bay	E	E	5	†	..	16	..	..	600	1 : 12·2	2·0	1·94	310	2·8	High	324	Medium	
9	Scrap handling	B_1	D	10	21	0·68	32	1·03	1·52	610	1 : 9·6	1·75	1·75	350	3·25	Medium	468	High	
10	Plate handling	B_1	C	25	80	0·76	68	0·65	0·85	580	1 : 16·25	3·0	1·73	336	3·3	Medium	518	High	
11	Overhead charger	B_1	C	5	70	0·93	68	0·91	0·97	580	1 : 13·8	2·75	1·60	363	3·5	Medium	423	High	3
12	Ground charger	A	N	4	82	0·95	40	0·47	0·49	500	1 : 11·2	2·5	1·42	351	3·7	Medium	462	High	
13	Soaking-pit charger	B_1	C	5	116	0·96	68	0·56	0·59	580	1 : 13·8	2·75	1·60	363	3·7	Medium	444	High	
14	Ingot handling	E	F	5	†	..	11·5	..	..	510	1 : 11·2	2·04	1·75	292	3·25	Medium	321	Medium	
15	Stripper	F	..	4	130	0·97	85	0·63	0·65	550	1 : 9·3	2·0	1·48	371	3·25	Medium	336	Medium	
16	Mould preparation and general purpose	E	E	20	†	..	25	..	..	570	1 : 19·6	2·17	2·88	197	3·4	Medium	327	Medium	
17	Box lifter and magnet	D_1	N	12	100	0·89	75	0·67	0·75	460	1 : 12·4	3·0	1·32	350	3·6	Medium	414	Medium	4
18	Ingot handling	B_1	G	60	60	0·50	67·5	0·56	1·13	580	1 : 20·9	3·0	2·22	262	3·6	Medium	348	Medium	
19	Box lifter and magnet	D_2	N	12	80	0·87	70	0·76	0·88	520	1 : 13·8	2·5	1·76	296	3·75	Medium	396	Medium	
20	Ladle	C	F	60	116	0·66	115	0·65	0·99	500	1 : 19·45	3·0	2·06	242	4·4	Low	324	Medium	
21	Ladle	C	N	150	190	0·56	150	0·44	0·79	500	1 : 23·1	3·0	2·45	204	5·0	Low	312	Medium	
22	Ladle	D_2	N	100	140	0·58	120	0·50	0·86	620	1 : 33·6	3·0	3·56	174	3·2	Medium	294	Low	5
23	Mill service	C	L	90	76	0·46	2 × 20	0·24	0·53	600	1 : 23·4	2·5	2·98	202	4·1	Low	285	Low	
24	Ladle	B_2	..	120	130	0·52	98	0·39	0·75	515	1 : 36·6	2·5	4·65	111	5·0	Low	232	..	
25	Mould preparation	D_2	C	25	85	0·77	35	0·32	0·41	575	1 : 25·6	2·5	3·26	176	3·95	Medium	229	..	
26	Box lifter	E	J	15	†	..	30	..	..	500	1 : 15·0	2·0	2·39	210	4·1	Low	340	Medium	‡
27	Ingot stripper	E	N	5	†	..	40	..	..	515	1 : 14·85	2·5	1·89	272	4·15	Low	328	Medium	
28	Soaking-pit charger	E	N	4	†	..	40	..	..	515	1 : 13·15	2·5	1·68	308	4·2	Low	345	Medium	
29	Scrap-handling magnet	E	E	12	†	..	25	..	..	570	1 : 15·2	2·17	2·23	256	4·5	Low	298	Low	
30	Scrap-handling magnet	E	B	12	†	..	25	..	..	330	1 : 15·35	3·0	1·63	203	4·6	Low	303	Medium	
31	General purpose	B_1	D	40	56	0·58	67·5	0·70	1·21	580	1 : 18·5	2·75	2·14	271	4·7	Low	435	High	
32	Scrap-handling magnet	B_2	K	10	55	0·85	68	1·05	1·24	580	1 : 12·75	3·0	1·35	428	4·0	Low	567	High	§
33	Overhead charger	E	N	4	†	..	30	..	..	500	1 : 10·45	2·0	1·67	301	3·8	Medium	357	Medium	

* Columns 3 and 4 give key letters for the steelworks and crane manufacturer corresponding to each motion
† The unladen weights of these cranes are not available at present
‡ Unclassified (inadequate performance)
§ Unclassified (unorthodox performance curves).

is that steelworks personnel can carry out quick tests on existing crane motions, classify them on the test results, and thus gain a quantitative standard of reference when ordering new cranes.

DETERMINATION OF PERFORMANCE CURVES

Tests were carried out at six steelworks, and from the results of these tests speed/time and distance/time curves for 33 long-travel and 35 cross-travel motions of steelworks E.O.T. cranes were obtained. The long-travel curves are given in Figs. 10 and 11 and the cross-travel curves in Figs. 17 and 18. Details of the tests are given in the Appendix.

Table I gives a list of the long-travel motions that were tested, together with relevant transmission details. Table II gives a similar list and transmission details for the cross-travel motions. In these tables, a column entitled "Revolutions of motor for 1 ft. motion of (crane) crab" has been included to give a basic comparison of the gear ratios and road-wheel diameters of the motions tested.

As far as possible only cranes which the production personnel considered were giving satisfactory performances were tested. Selection was also made so that the tested cranes formed a representative cross-section of the various types of steelworks cranes.

Table II

CLASSIFICATION OF CROSS-TRAVEL MOTIONS

Reference	Crane Duty	Steelworks*	Crane Maker*	Load, tons	Unladen Weight, tons	Unladen wt. Laden wt.	Rated Motor H.P.	Power/Weight Ratio, h.p./ton		Rated Motor Speed, r.p.m.	Gear Ratio	Dia. of Road Wheel, ft.	Revolutions of Motor for 1 ft. Motion of Crab	Geared Speed, ft./min.	Time to Move 20 ft. from rest, sec.	Class
								Laden	Unladen							
1	Magnet	A	N	15	15·5	0·51	15	0·49	0·97	500	1 : 11·7	1·50	2·48	202	5·35	*a*
2	Stock yard	A	A	20	20·0	0·50	25	0·63	1·25	500	1 : 10·8	1·33	2·58	194	5·65	
3	Grab and magnet	C	D	5	6·5†	0·57	10	0·87	1·54	750	1 : 12·5	1·00	3·98	189	5·8	
4	Mill loading	C	C	15	8·3	0·36	10	0·43	1·21	750	1 : 16·2	1·25	4·12	182	5·95	
5	Beam loading	C	M	5	6·0	0·55	10	0·91	1·67	750	1 : 15·0	1·00	4·77	157	6·0	
6	General purpose	C	C	15	6·0	0·29	10	0·48	1·67	750	1 : 19·1	1·25	4·87	154	6·05	
7	General purpose and ingot handling	D_2	N	10	††	..	15	..	..	650	1 : 25·0	1·50	5·30	123	6·8	
8	Box lifter and magnet	D_2	N	12	††	..	15	..	..	650	1 : 17·0	1·50	3·61	180	7·15	*b*
9	Ladle (auxiliary crab)	A	N	140/25	11·5	0·32	15	0·41	1·30	500	1 : 21·0	1·33	5·03	100	7·2	
10	Stripper	C	F	4	43·0	0·91	20	0·43	0·47	750	1 : 20·9	1·25	5·32	141	7·3	
11	Ground charger	A	N	4	42·0	0·91	25	0·54	0·60	500	1 : 13·2	1·33	3·16	158	7·35	
12	Mould handling magnet	C	M	7	3·0	0·30	5	0·50	1·67	750	1 : 13·3	0·83	5·10	147	7·4	
13	Magnet	D_2	N	7	††	..	$7\frac{1}{2}$	..	..	700	1 : 16·2	0·87	5·92	118	7·7	
14	Mill loading	C	C	10	††	..	10	..	..	750	1 : 20·0	1·00	6·37	118	7·8	
15	Box lifter and magnet	D_1	N	12	††	..	25	..	..	535	1 : 16·7	1·96	2·72	197	7·9	
16	Magnet	A	H	20	16·0	0·44	15	0·42	0·94	500	1 : 23·1	1·50	4·90	102	8·0	
17	Mill service	A	A	60	17·3	0·22	15	0·19	0·87	500	1 : 34·4	1·75	6·25	80	8·1	
18	Soaking-pit charger	C	F	4	27·8	0·87	10	0·31	0·36	750	1 : 18·5	1·25	4·72	159	8·25	
19	Scrap-handling magnet	C	N	10	19·0	0·65	5	0·17	0·26	750	1 : 14·9	0·87	5·45	138	8·75	
20	Ladle	D_2	N	100	††	..	30	..	..	640	1 : 49·3	2·00	7·84	82	8·75	
21	Slab charger	A	Z	12	39·7	0·77	25	0·63	..	500	1 : 27·9	1·75	5·08	99	9·05	
22	Stripper	A	N	6	61·5	0·88	25	0·36	0·41	500	1 : 19·4	1·50	4·12	121	9·25	
23	Ladle	D_1	I	100	††	..	35	..	..	525	1 : 60·0	1·95	9·78	54	9·35	
24	Ingot-handling magnet	C	L	5	4·5	0·47	5	0·53	1·11	750	1 : 15·9	0·75	6·75	111	9·4	
25	Magnet	D_1	H	$12\frac{1}{2}$	††	..	10	..	..	750	1 : 14·1	1·00	4·48	167	9·45	
26	Mill service	C	L	90	27·0	0·23	10	0·09	0·37	750	1 : 59·4	2·00	9·44	79	9·55	*c*
27	Mill service	A	L	15	12·4	0·45	5	0·18	0·40	600	1 : 33·7	1·33	8·07	75	9·75	
28	Mill service	C	L	20	11·0	0·35	5	0·16	0·45	750	1 : 43·9	1·25	11·20	67	10·45	
29	Ladle (main crab)	A	N	140/25	51·0	0·27	25	0·13	0·49	500	1 : 56·1	1·33	7·13	70	10·5	
30	Ladle	C	D	60	27·3	0·31	25	0·29	0·92	570	1 : 44·7	2·50	7·11	80	10·75	
31	Mould preparation	C	C	25	††	..	$7\frac{1}{2}$	..	..	925	1 : 44·5	1·50	10·28	90	11·8	
32	Ladle (main crab)	D_2	E	100/25	33·0	0·25	25	0·19	0·76	500	1 : 50·0	2·25	9·08	71	11·2	
33	Ladle	C	F	60	33·0	0·36	20	0·22	0·61	750	1 : 58·7	2·00	7·35	80	12·3	
34	Ladle (auxiliary crab)	C	N	150/30	11·5	0·28	10	0·24	0·87	750	1 : 51·4	1·35	12·12	62	13·4	
35	Ladle (main crab)	C	N	150/30	49·0	0·25	30	0·15	0·61	600	1 : 78·5	2·50	10·00	60	13·8	

* Columns 3 and 4 give key letters for the steelworks and crane manufacturer corresponding to each motion

† This weight does not include the weight of magnet and grab

†† The unladen weights of these crabs are not available at present.

CONVENTION OF DISTANCE SYMBOLS ON SPEED/TIME CURVES

In comparing the speed/time curves of various motions a convention has been adopted by which the time taken for a motion to travel a certain fixed distance can be ascertained from the curves. This convention consists of superimposing a geometrical symbol (representing a distance x) on the speed/time curve of a motion at such a position that the time ordinate of the symbol is the time taken by the motion to move the distance x (*see* Fig. 3).

Thus if the symbol Δ is used to represent a distance of x ft., then from the placing of this symbol (*see* Fig. 3) it is at once apparent that the motion took a time t to move a distance x. A series of symbols was built up on all the speed/time curves so that the three variables of speed, time, and distance could be studied on one diagram.

Figure 10 shows that the distance symbols for 8 ft. lie in a curved band. This approximates to a hyperbola because the speed/time curves up to this point approximate to straight lines.

An illustration of the usefulness of this convention is given by Fig. 4, which shows two speed/time curves representing the long-travel motions of two cranes A and B. Crane A has a high acceleration and medium speed, and crane B has a medium acceleration and high speed. The circles, triangles, and squares are the distance symbols which represent distances of 20 ft., 50 ft., and 80 ft. respectively. It is now apparent that crane A will travel 20 ft. in a shorter time than crane B; that both cranes take the same time to travel 50 ft.; and finally that crane B will travel 80 ft. in a shorter time than crane A.

CLASSIFICATION OF LONG-TRAVEL MOTIONS

To form a system of classification from the performance curves (*see* Figs. 10 and 11), the need is apparent for simple criteria which, when applied to the curves, will give a sufficiently rigid definition of their form.

Several criteria were devised, all having sufficient simplicity, but all failing, since they did not define the curves adequately. Finally, on the basis indicated on p. 441, criteria were devised which gave each motion a class for initial acceleration and also for speed, and various combinations of these classes were then used to produce an overall general classification for each motion. The criteria and subsequent classification are described in detail in this section.

Initial Acceleration Classification

From the speed/time curves shown in Fig. 10 it can be seen, by reference to the distance symbols, that the initial slopes of the majority of curves are sensibly straight during the time taken by the motions to reach 8 ft., but that after this time the curves rapidly bend away and begin to approach their balancing speeds. Thus if acceleration is assessed at any time during the period when the motion has moved its first 8 ft., it will be representative of the initial acceleration, which under ideal conditions is constant.

The initial accelerations of the motions were compared by reference to Fig. 10 and it was found that a convenient division could be made by stating that

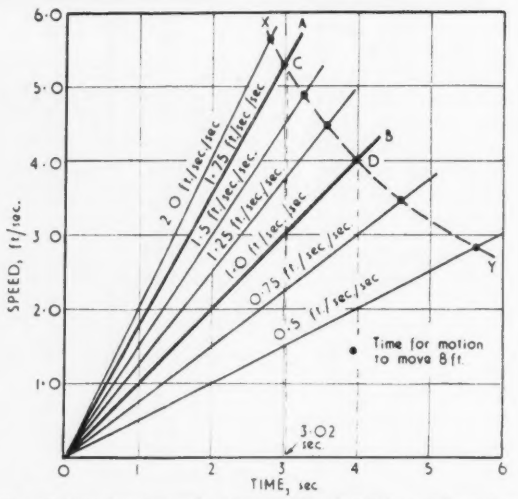


Fig. 5—Derivation of criteria for initial acceleration classification

motions having an initial acceleration less than 1·0 ft./sec./sec. had a low initial acceleration, that motions having an initial acceleration between 1·0 and 1·75 ft./sec./sec. had a medium initial acceleration, and that motions having an initial acceleration greater than 1·75 ft./sec./sec. had a high initial acceleration. The simplest way of testing these accelerations in a steelworks is by timing the motion over a fixed distance from rest, and for this purpose a distance of 8 ft. was chosen because it leads to simple test figures and because, as has already been stated, the initial acceleration for most motions lasts for 8 ft.

Figure 5 is a speed/time graph which shows a series of straight lines representing various values of constant acceleration. The lines OA and OB have been emphasized and represent accelerations of 1·75 and 1·0 ft./sec./sec. respectively. Distance symbols for 8 ft. have been superimposed on these lines, as shown by the dotted line XY. The intersection of XY with OA and OB occurs at C and D, and as shown by Fig. 5, C corresponds to a time of 3·02 sec. and D to a time of 4·00 sec. Thus if a motion has an initial acceleration of 1·75 ft./sec./sec. it will travel 8 ft. from rest in 3·02 sec., and if it has an initial acceleration of 1·0 ft./sec./sec. it will travel 8 ft. from rest in 4·00 sec. On this basis the following system of initial acceleration classification was adopted :

(*a*) A motion which travels 8 ft. in less than 3 sec. is classed as one having a high initial acceleration
(*b*) A motion which travels 8 ft. in 3–4 sec. is classed as one having a medium initial acceleration
(*c*) A motion which travels 8 ft. in more than 4 sec. is classed as one having a low initial acceleration.

The acceleration classification on the distance/time graph is shown in Fig. 6. On this basis a motion will have a high, medium, or low initial acceleration according to whether its distance/time curve passes to the left, through, or to the right of the 'gate' shown in the figure.

This acceleration classification can also be shown

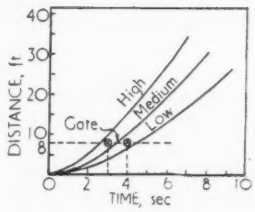


Fig. 6

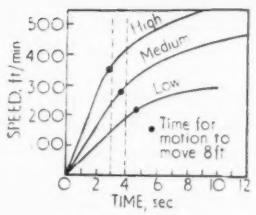


Fig. 7

Fig. 6—Initial acceleration classification on distance/time curves

Fig. 7—Initial acceleration classification on speed/time curves

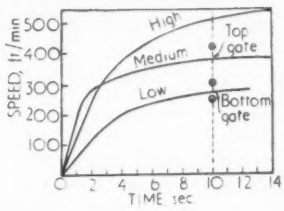


Fig .8

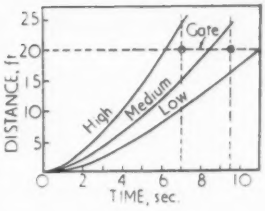


Fig. 9

Fig. 8—Speed classification on speed/time curves

Fig. 9—Cross-travel classification on distance/time curves

on the speed/time graph with the help of the 8-ft. distance symbol, as illustrated in Fig. 7. A motion will have a high, medium, or low initial acceleration according to whether the 8-ft. symbol falls to the left, between, or to the right of the vertical dotted lines drawn from the 3 and 4-sec. marks on the time axis.

The acceleration class criteria illustrated in Figs. 6 and 7 are superimposed on Figs. 10 and 11 containing the speed/time and distance/time curves of the long-travel motions tested. In Table I the motions are classified on this initial acceleration basis.

Speed Classification

Having defined the initial part of the speed/time curves it now remains to find some criterion which will 'fix' the form of the subsequent part of these curves. From Fig. 10 it will be seen that after a time of 10 sec. the majority of the curves have flattened out appreciably although they are not near their balancing speeds. This 10-sec. point appeared suitable for use as a standard for the comparison of the motion speeds, and from a further study of the speed/time curves in Fig. 10 the following speed classification was adopted :

(*a*) A motion having a speed greater than 420 ft./min. after travelling from rest for 10 sec. is classed as one having a high speed

(*b*) A motion having a speed between 300–420 ft./min. after travelling from rest for 10 sec. is classed as one having a medium speed

(*c*) A motion having a speed between 240–300 ft./min. after travelling from rest for 10 sec. is classed as one having a low speed.

The speed classification on the speed/time graph is shown in Fig. 8. On this basis the motions are classed as having a high, medium, or low speed according to whether the speed/time curve passes above the double gate, through the top gate or through the bottom gate shown in the figure. The speed class recorded in Table I is determined on this basis.

General Classification

There are nine possible ways in which the initial acceleration and speed classes may be combined :

(i) High acceleration—high speed
(ii) High acceleration—medium speed
(iii) High acceleration—low speed
(iv) Medium acceleration—high speed
(v) Medium acceleration—medium speed
(vi) Medium acceleration—low speed
(vii) Low acceleration—high speed
(viii) Low acceleration—medium speed
(ix) Low acceleration—low speed.

None of the tested motions which had speed/time curves of orthodox form (as shown in Figs. 1 and 2), fell into classes (iii) and (vii), and therefore these were ignored, leaving seven possible general classes.

This number is still too large for practical use. West classified steelworks cranes into the long-travel motions of three classes (*see* p. 440), but, although his classes were adequately represented in Fig. 10, there was no provision for two classes of travel motions which might be said to have 'superlative' and 'mediocre' performances respectively. Finally five classes were defined; three of these were based on those defined by West, and two new classes were added. Their characteristics and relations to the original seven and to West's classes are as follows :

Class	Description	Remarks
1	A motion having a high initial acceleration and a high speed	Based on class (i); 'superlative' class
2	A motion having a high initial acceleration and a medium speed	Based on class (ii) and on West's class 1
3	A motion having a medium initial acceleration and a high speed	Based on class (iv) and on West's class 2
4	A motion having a medium initial acceleration and a medium speed	Based on class (v); 'mediocre' class
5	A motion having no specific acceleration class but which must have a speed of at least 240 ft./min. after travelling from rest for 10 sec. (This class of motion will normally have a low acceleration and low speed, but may possibly have a medium acceleration and low speed or low acceleration and medium speed.	Based on classes (vi), (viii), and (ix), and on West's class 3

This system of classification can be traced on the curves shown in both Figs. 10 and 11, but Fig. 10 showing the speed/time curves gives the more unified picture of the classification. To clarify the system, the speed/time curves of long-travel motions, in each of the classes 1 to 5 have been plotted separately in Figs. 12 to 16 respectively. Table I has been divided on the basis of this final classification.

Comments on Classification

Examination of Table I shows that, in general, classes 1, 2, 3, and 4 cover long-travel motions of cranes for carrying loads of anything up to 60 tons, whilst class 5 covers motions of cranes for carrying loads of anything over 60 tons, *e.g.*, ladle cranes.

From an examination of acceleration and speed characteristics it can be shown that :

(*a*) Class 1 long-travel motions give optimum performance over all trip distances, since they have both high acceleration and high speed

(*b*) Class 2 long-travel motions give optimum performance over short trip distances (up to 50 ft., approx.) because of their high acceleration

(*c*) Class 3 long-travel motions give optimum performance over long trip distances (any distance over 50 ft. approx.) because of their high speed

(*d*) Class 4 long-travel motions give a mediocre performance over all trip distances.

Table I shows that motions 31 to 33 have been excluded from the classification even though motion 32 almost fits into class 3 and motion 33 fits into class 4. This has been done because the initial parts of the speed/time curves of all these motions are unorthodox in form (*see* Fig. 10). It is possible that the cause of this departure from the usual form of the speed/time curves (as shown in Figs. 1 and 2) was maladjustment of the motor control gear.

The speed/time curves of motions 24 to 30 all have orthodox forms and yet they do not fit into any of the classes. The performance of these motions is considered to be inadequate in comparison with the rest of the motions tested.

CLASSIFICATION OF CROSS-TRAVEL MOTIONS

The speed/time and distance/time curves for the cross-travel motions are given in Figs. 17 and 18.

An examination of the speed/time curves in Fig. 17 shows that it is not possible to classify the cross-travel motions in a way similar to the one adopted for the long-travel motions, since the initial slopes of the curves cease to be sensibly straight long before the motion reaches a distance of 8 ft., and any attempt to time a motion over distances of less than 8 ft. would not be possible without using a complicated testing technique. It was therefore decided to take account of both acceleration and speed, more or less implicitly, by comparison of the times taken by the cross-travel motions to move a fixed distance from rest. The reference distance chosen was 20 ft. since, as can be seen from Fig. 17, most of the speed/time curves have started to flatten out at this distance, and therefore initial acceleration and speed will both be inherently taken into account. After careful study

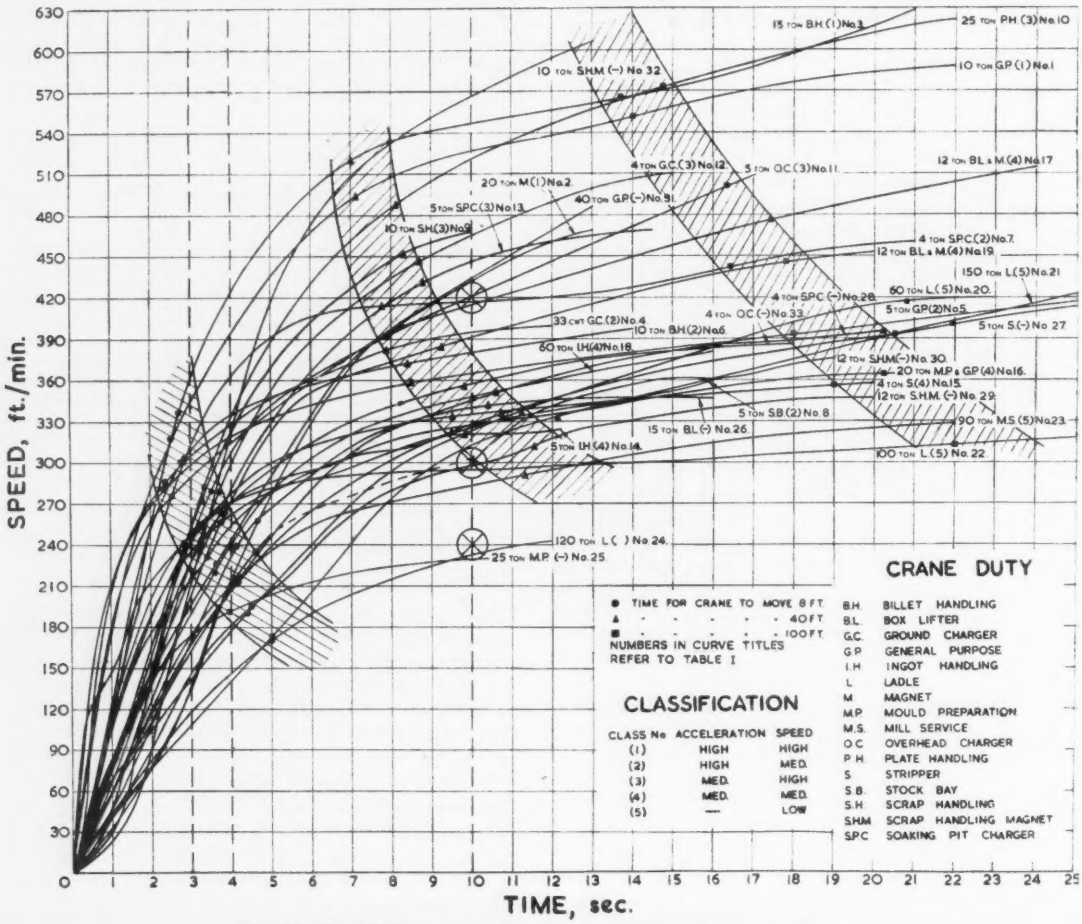


Fig. 10—Speed/time curves for all classes of long-travel motion

of the performance curves (*see* Figs. 17 and 18) the following classification was adopted :

(i) *Class a*—A motion which travels 20 ft. from rest in less than 7·0 sec. (high performance)
(ii) *Class b*—A motion which travels 20 ft. from rest in 7·0–9·5 sec. (medium performance)
(iii) *Class c*—A motion which travels 20 ft. from rest in more than 9·5 sec. (low performance).

This classification is interpreted on the distance/time graph in Fig. 9, which shows how a motion may be classed as having a high, medium, or low performance according to whether its distance/time curve passes to the left, through, or to the right of the gate shown.

The classification of the motions is shown on the distance/time curves in Fig. 18, on the speed/time curves (with the aid of the 20-ft. distance symbols) in Fig. 17, and has also been tabulated in Table II.

Comments on Classification

From an examination of Table II it can be seen that classes *a* and *b* cover cross-travel motions of cranes for carrying loads of anything up to 60 tons, while class *c* covers motions of cranes for carrying loads of anything over 60 tons, *e.g.*, ladle cranes.

PERFORMANCE SPECIFICATION AND ACCEPTANCE TESTS

Performance Specification .

The B.I.S.R.A. specification[2] for steelworks cranes takes account of travel-motion performance quantitatively, on the basis described above, and includes tables (reproduced here as Tables III and IV) giving the various classes of long-travel and cross-travel motions as described in the preceding two sections. When ordering a new crane to which a duty cycle cannot be assigned, the purchaser will choose the class of long-travel motion and the class of cross-travel motion he requires, and specify these in Appendix I of the specification.

Acceptance Tests

Specifying crane performance by this method lends

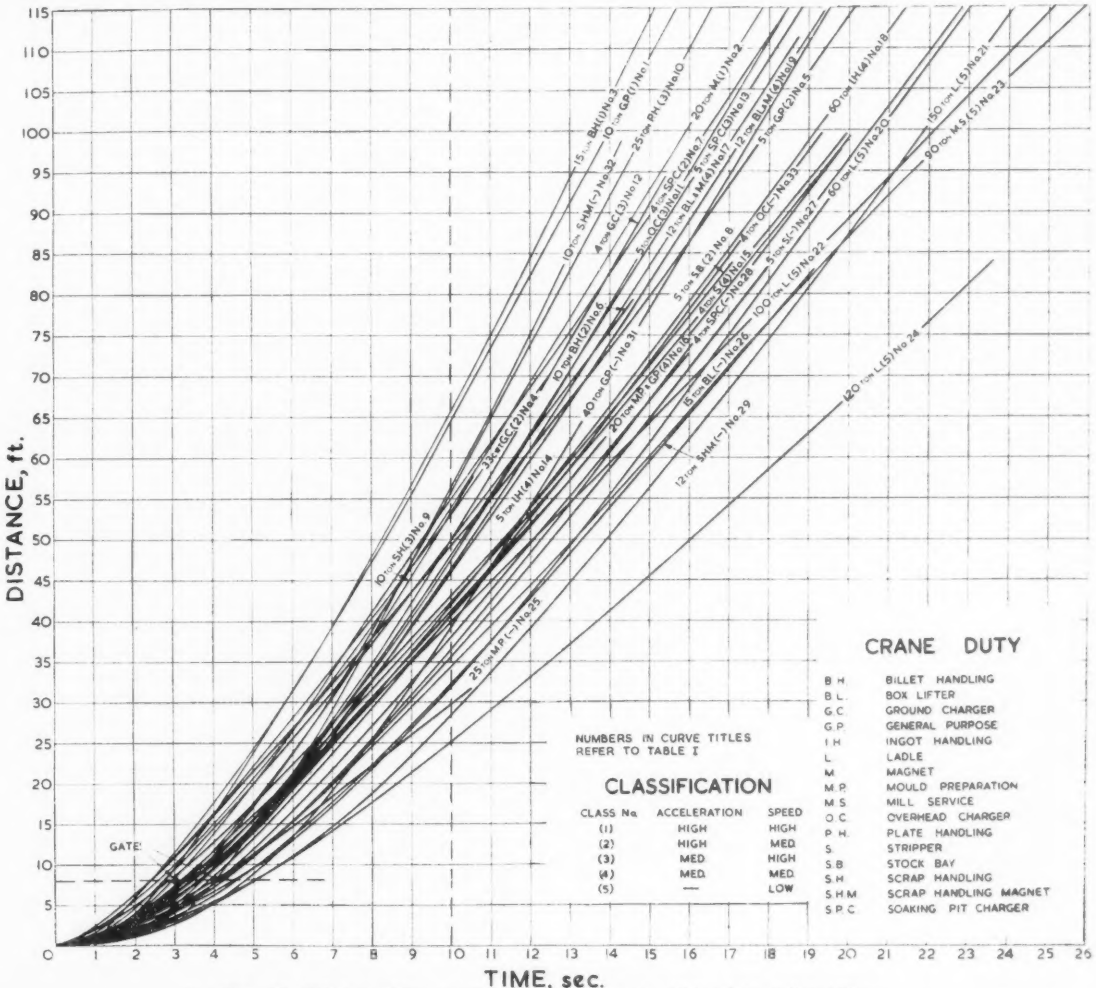


Fig. 11—Distance/time curves for all classes of long-travel motion

Table III

PERFORMANCE OF LONG-TRAVEL MOTION

Type of Crane	Class of Motion	Time for Crane to Travel 8 ft. from rest, sec.*	Speed of Crane after Travelling for 10 sec. from rest, ft./min.	Characteristics of Motion: Acceleration	Characteristics of Motion: Speed	Approximate Trip Distance, ft.
Severe duty cranes, for example:						
Charging machines Despatching dept. cranes Finishing dept. cranes Scrap yard cranes Skull-breaking cranes Soaking-pit cranes Stripper cranes Stock bay cranes	1	Less than 3	Greater than 420	High	High	All distances
	2	Less than 3	300–420	High	Medium	Less than 50
	3	3–4	Greater than 420	Medium	High	More than 50
	4	3–4	300–420	Medium	Medium	...
Medium duty cranes, for example:						
Ladle cranes Mill service cranes	5	Not specified	Greater than 240	...	Slow	...

* The data in column 3 of this table are not mandatory. They are, however, recommended as representative of good long-travel performance

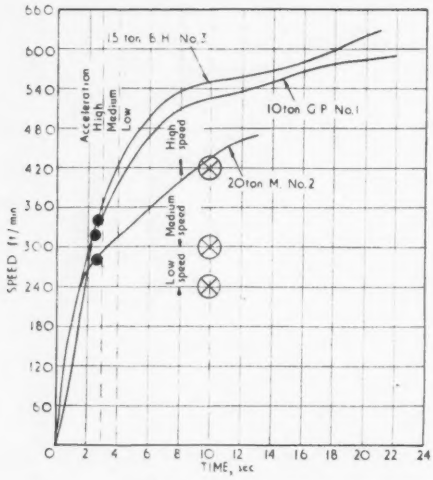
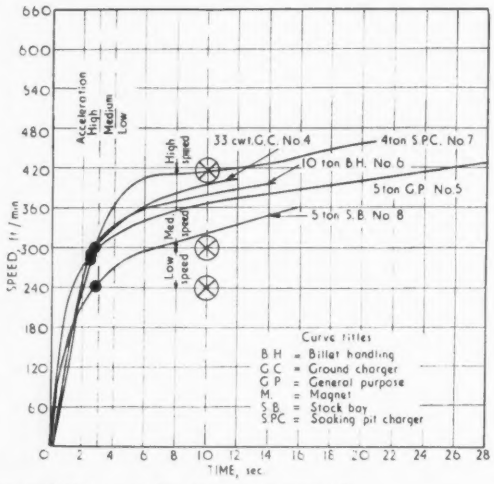


Fig. 12—Long-travel speed/time curves for class 1 cranes (high acceleration, high speed)



Numbers given in curve titles are references to Table I ● Time for crane to move 8 ft.

Fig. 13—Long-travel speed/time curves for class 2 cranes (high acceleration, medium speed)

Table IV

PERFORMANCE OF CROSS-TRAVEL MOTION

Type of Crane	Class of Motion	Time for Crab to Travel 20 ft. from rest, sec.	Characteristics of Motion
Severe duty cranes, for example:			
Charging machines Despatching dept. cranes Finishing dept. cranes Scrap yard cranes Skull-breaking cranes Soaking-pit cranes Stripper cranes Stock bay cranes	*a*	Less than 7·0	High performance
	b	7·0–9·5	Medium performance
Medium duty cranes, for example:			
Ladle cranes Mill service cranes	*c*	Not specified	Low performance

itself to very simple acceptance tests. To test the long-travel motion, the motion has to be timed from rest over a distance of 8 ft. and its speed measured after it has travelled from rest for 10 sec. This can be done by marking the gantry with two marks 8 ft. apart and timing the motion from rest over this distance with a stop-watch. The speed of the motion can conveniently be measured by a hand tachometer held on to the motor or other drive shaft of the motion.

To test the cross-travel motion it is necessary only to determine the time it takes to move a distance of 20 ft., starting from rest.

CONCLUSION

It should be pointed out that this paper is a first attempt at dealing with a subject beset with many difficulties, and as such it is bound to be somewhat tentative. It is probable that further experience will modify the ideas presented to some extent, but it is hoped that they will be considered sufficiently constructive to form a basis for further study.

Acknowledgments

Thanks are due to the managements of the steelworks visited, who gave permission for the tests to be carried out, and also to those who gave their help and co-operation during the tests.

APPENDIX

Determination of Performance Curves

All motions were accelerated as fast as possible during the tests. Three successive techniques were used to obtain the performance curves given in Figs. 10 to 18, each technique giving improved accuracy over its forerunner.

Technique 1—This technique was used only for the early testing on long-travel motions.

The distance/time curve for each crane was determined by timing the crane from rest as it passed various distance marks on the gantry. Three observers stood on the bridge of the crane, each with two stop-watches, and sighted along the handrail or other convenient part of the crane on to the distance marks on the gantry.

Each point on the distance/time curve as finally obtained was an average taken from six runs of the crane; to obtain enough data to plot a complete curve approximately 30 runs of the crane were necessary.

The speed/time curves were obtained from the distance/time curves by graphical differentiation.

Technique 2—This technique was used only for testing long-travel motions.

Data for plotting the distance/time curve were recorded automatically on a clockwork-driven chronograph, a single recording stylus being operated by a contact maker, belt-driven from a motion shaft, and by a Cambridge contact-clock giving $\frac{1}{10}$-sec. time intervals.

The speed/time curves were obtained as in technique 1.

Technique 3—This technique was used for both long-travel and cross-travel motions.

A ciné camera was used to photograph a hand tachometer and a Venner 10-sec. stop-watch, mounted side by side. The tachometer was held on to a convenient drive shaft of the motion (the motor shaft where possible). The camera had a clockwork drive, used 35-mm. film, and was run at 8 frames/sec. The camera, stop-watch, and tachometer, together with a lamp for illuminating the tachometer and stop-watch, were mounted rigidly on a wooden board, thus forming a unit which could easily be carried from crane to crane.

In the case of the cross-travel motions it was not always possible for the operator to station himself safely on the crab and to hold the tachometer in position on a drive shaft. In this case a weighted rope was attached to the crab and passed over a pulley mounted on the crane bridge. The test equipment was then clamped into position close to the pulley, which was used to drive the tachometer spindle. With this method the test run of the crab was limited by the height of the pulley from the ground.

This technique gave the speed/time curves of the

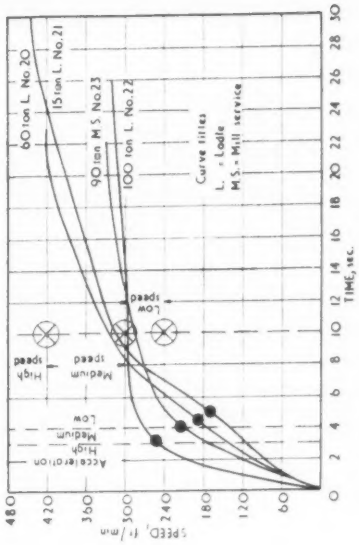


Fig. 16—Long-travel speed/time curves for class 5 cranes (no specified acceleration, but speed must be greater than 240 ft./min. after 10 sec.)

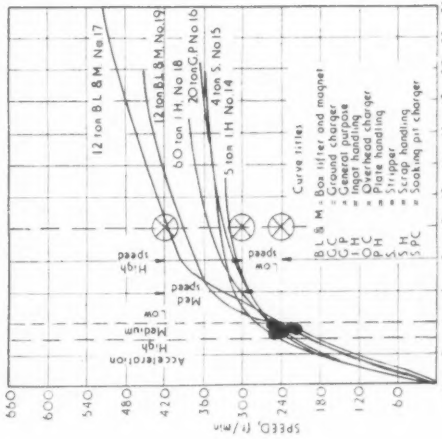


Fig. 15—Long-travel speed time curves for class 4 cranes (medium acceleration, medium speed)

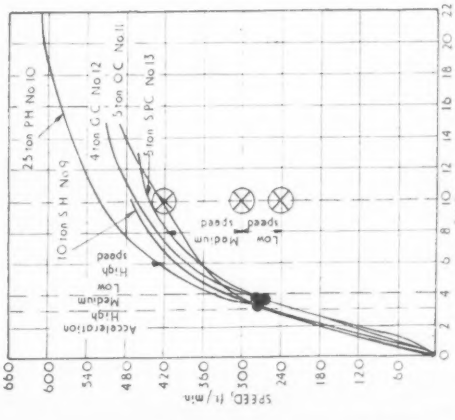


Fig. 14—Long-travel speed/time curves for class 3 cranes (medium acceleration, high speed)

motions, and the distance/time curves were obtained from them by graphical integration.

Comments on Technique

A disadvantage of technique 1 was the time needed to test a crane. This was about 45 min., and as the time for a test was limited to the time a crane was not required for production, difficulty was often experienced in completing a test on some of the more heavily worked cranes.

Technique 2 was an improvement on technique 1 on the score of accuracy, but the amount of time and labour necessary for the interpretation of the test data was a disadvantage.

Technique 3 was considered to be superior to the others in almost all respects. It gave the most accurate performance curves and the testing time was considerably shortened. The time needed for interpretation of the test results was also less than that required with technique 2.

Load Swing on Cross-Travel Motions

Where a crab has a magnet or a heavy load suspended on the hoist ropes, the magnet or load will develop a ' load swing ' during the motion of the crab. This load swing has the effect of alternately assisting and opposing the motion of the crab and so causes a cyclical variation of crab speed. The full line in Fig. 19*a* shows this speed variation on one of the tested motions, whilst the dotted line shows the anticipated speed/time curve on the assumption of no load swing. The dotted and full curves in Fig. 19*a* have been integrated to give the corresponding distance/time curves shown in Fig. 19*b*. The difference between the dotted and full curves of distance/time is seen to be small and it does not

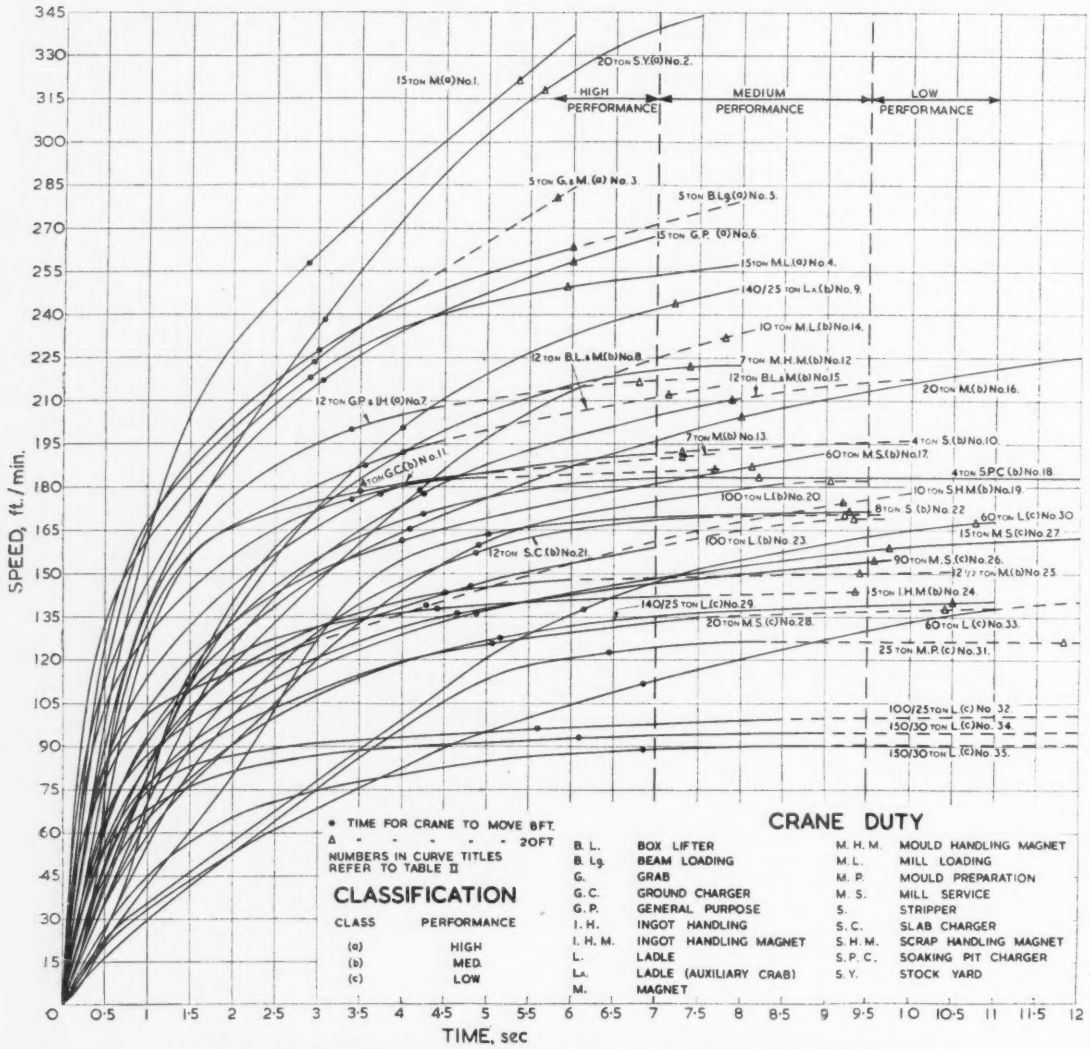

SPEED, ft./min.
TIME, sec
HIGH PERFORMANCE
MEDIUM PERFORMANCE
LOW PERFORMANCE
15 TON M(a) No.1.
20 TON S.Y.(a) No.2.
5 TON G. & M. (a) No. 3.
5 TON B.Lg.(a) No.5.
15 TON G.P. (a) No.6.
15 TON M.L.(a) No.4.
140/25 TON L.A.(b) No.9.
10 TON M.L.(b) No.14.
12 TON B.L.& M.(b) No.8.
7 TON M.H.M.(b) No.12.
12 TON B.L.& M.(b) No.15.
12 TON G.P. & I.H. (a) No.7.
20 TON M.(b) No.16.
7 TON M.(b) No.13.
4 TON S.(b) No.10.
4 TON G.C.(b) No.11.
60 TON M.S.(b) No.17.
4 TON S.P.C. (b) No.18.
10 TON S.H.M.(b) No.19.
100 TON L.(b) No.20.
8 TON S. (b) No.22.
60 TON L.(c) No.30.
100 TON L.(b) No.23.
15 TON M.S.(c) No.27.
12 TON S.C.(b) No.21.
90 TON M.S.(c) No.26.
12 1/2 TON M.(b) No.25.
15 TON I.H.M.(b) No.24.
140/25 TON L.(c) No.29.
20 TON M.S.(c) No.28.
60 TON L.(c) No.33.
25 TON M.P.(c) No.31.
100/25 TON L.(c) No.32.
150/30 TON L.(c) No.34.
150/30 TON L.(c) No.35.
• TIME FOR CRANE TO MOVE 8FT.
Δ - - - - - - 20FT
NUMBERS IN CURVE TITLES REFER TO TABLE II
CLASSIFICATION
CLASS PERFORMANCE
(a) HIGH
(b) MED.
(c) LOW
CRANE DUTY
B. L. BOX LIFTER
B. Lg. BEAM LOADING
G. GRAB
G. C. GROUND CHARGER
G. P. GENERAL PURPOSE
I. H. INGOT HANDLING
I. H. M. INGOT HANDLING MAGNET
L. LADLE
La. LADLE (AUXILIARY CRAB)
M. MAGNET
M. H. M. MOULD HANDLING MAGNET
M. L. MILL LOADING
M. P. MOULD PREPARATION
M. S. MILL SERVICE
S. STRIPPER
S. C. SLAB CHARGER
S. H. M. SCRAP HANDLING MAGNET
S. P. C. SOAKING PIT CHARGER
S. Y. STOCK YARD

Fig. 17—Speed/time curves for all classes of cross-travel motion

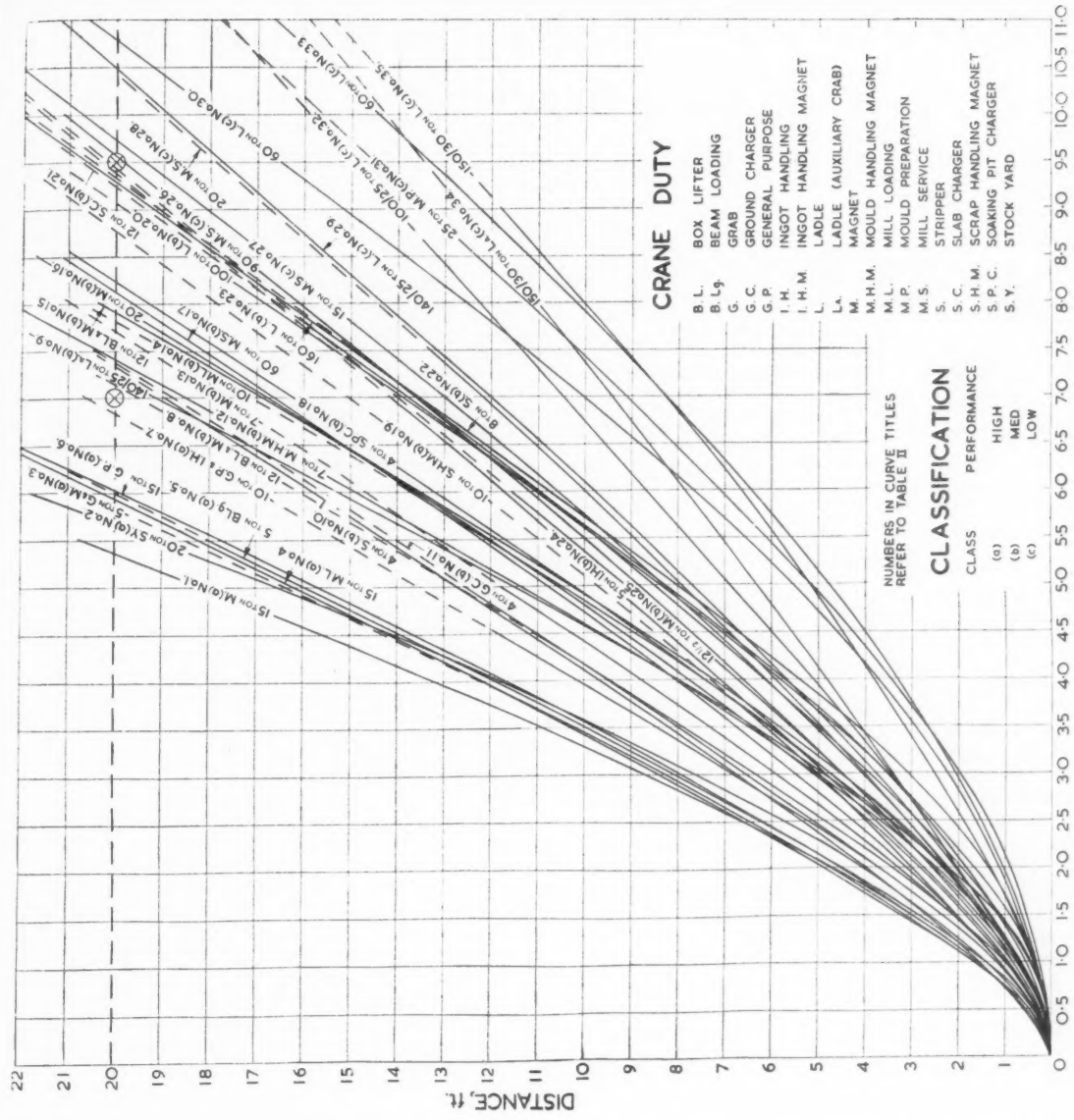


Fig. 18—Distance/time curves for all classes of cross-travel motion

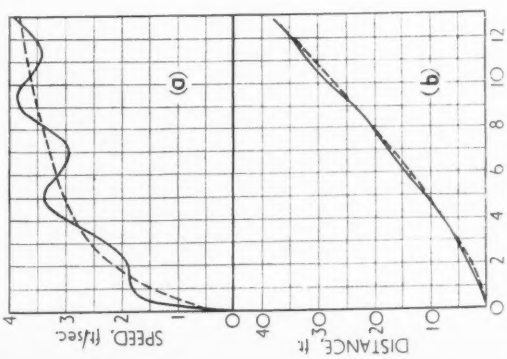


Fig. 19—Effect of load swing on cross-travel motion on (*a*) speed/time and (*b*) distance/time curves

sensibly influence the results of the classification.

As a result of this conclusion wavy speed/time curves obtained from tests on crabs carrying magnets, or similar heavy loads capable of swinging, have been smoothed and the distance/time curves obtained by integration of these smoothed curves.

References

1. R. A. WEST: "Electric Traction for Cranes." 1945, Pitman, London.
2. American Crane Specification, *Standard No.* 6. 1949, Association of Iron and Steel Engineers.
3. Specification for Heavy Duty Electric Overhead Travelling Cranes for use in Iron and Steel Works. 1950, The British Iron and Steel Research Association.

Characteristics of Scrap in Relation to Bulk Handling

By E. L. Diamond, M.Sc.(Eng.), M.I.Mech.E.

SYNOPSIS

A very great increase in the rate of supply of scrap to large melting or steelmaking furnaces will probably be obtainable only by a departure from the pan method of loading. An essential preliminary to the successful development of alternative methods of bulk handling is a fundamental knowledge of the relationships between the shape of pieces of scrap and the packing and flow of large quantities of similar pieces.

For the purpose of an investigation into these relationships all scrap may be regarded as pieces having two principal dimensions perpendicular to each other, ranging from sheets with a length and a thickness, to rods or bars with a length and a diameter ; or as combinations or mixtures of such pieces. Experiments were carried out on quantities of uniform cylinders ranging from thin flat discs to long rods. Simple relationships were established between the principal dimensions (length and diameter) and (*a*) the bulk density of the pieces when dropped at random into a receptacle, and (*b*) the ability of the pieces to flow and separate, *e.g.*, in discharge from a chute to a receptacle.

From these experiments are drawn a number of conclusions which may be used in the control of the segregation or preparation of scrap suitable for bulk handling, and which would give valuable guidance in the design of suitable equipment.

Introduction

It has been shown in a recent report on "Present Methods of Open-Hearth Furnace Charging"* that the limitation to the speed with which groups of large open-hearth furnaces can be charged is the rate at which scrap can be supplied to the chargers ; and that any radical improvement in furnace design, making possible much faster rates of melting, would necessitate either scrap preparation on a large scale, or the introduction of new methods of bulk handling, or both. The development of bulk-handling equipment without scrap preparation may be ruled out ; scrap segregation or preparation is the basis of all such developments unless or until some new kind of gigantic melting-furnace is perfected into which truck-loads of scrap can be directly discharged.

Even if the last-mentioned possibility were achieved, it might still be economical to segregate favourable types of scrap for direct melting in a steelmaking furnace. Again, the storage of scrap tends to be avoided at present because indiscriminate dumping leads to a tangled heap from which it is sometimes more costly to reload than from the original wagon-loads. Scrap segregation, to be of real value, must be carried out according to some clearly defined limits of size and shape. Before attempting any large-scale and costly treatment of scrap, there should be a clear understanding of the effect of the size and shape of individual pieces on the behaviour of the mass as a whole, so that such treatment can be designed to give well-defined results at the minimum cost.

Such preparation as is at present carried out, principally in the form of baling and flame-cutting, is directed to the simple aim of producing individual compact pieces that will fit a charging pan. That is also the basis of scrap specifications. If, however, the scrap, or a proportion of it, is to be handled by conveyor, chute, or other continuous mechanical means, such a criterion would be useless in preventing frequent blockages of one kind or another.

It is not contemplated that it would be economical to entirely eliminate pan loading of scrap supplied to existing specifications. Mill scrap, however, constitutes a large proportion of the whole in many works, and it should be possible to prepare this at source if the optimum limits of size and shape can be determined, so that the whole of it could be handled as a continuous supply, from a central collecting point to the melting-shop.

The purpose of the investigation was to ascertain the basic physical facts from which rules and limits can be formulated with some precision to satisfy these requirements, and from which guiding principles can be elucidated both for designing new types of mechanical handling plant, and for a preliminary assessment of the economic return likely to be obtained from such a plant. The problem of bulk density is relatively straightforward ; that of bulk handling is more complex, and it will be discussed in a later section. It may be defined as the ability to be discharged with ease from a chute to a receptacle, or *vice versa*. As will be seen later, these two attributes, namely high bulk density and ease of handling, are not always coincident.

NATURE OF THE PROBLEM

The Generalized Representation of Scrap

For the purpose of determining the effect of shape on the behaviour of quantities of individual pieces, it is desirable at first that all the pieces in each quantity studied should be exactly similar. It was

* E. L. Diamond and A. M. Frankau, *Journal of The Iron and Steel Institute*, 1949, vol. 161, March, p. 191.

Paper PE/D/35/49 of the Mechanical Engineering Committee of the Plant Engineering Division of the British Iron and Steel Research Association, received 19th September, 1949. The views expressed are the author's and are not necessarily endorsed by the Committee as a body.

Mr. Diamond is Assistant Technical Director of the British Standards Institution.

obviously also convenient that the pieces should be fairly small. The first requirement raised the difficult question as to how the infinite variety of scrap could be represented by a relatively small range of shapes, of each of which many thousands or even millions of pieces would be required. The propriety of using small pieces in a laboratory depends on the absence or presence of scale effect, and will be dealt with in a subsequent section.

To eliminate irrelevant variables there is another requirement, considerably simplifying the apparently hopeless task of reducing a scrap heap to scientific order, which is that the effect of shape and size may be separated. If, as experiment and theory indicate, scale effect is absent or at most a secondary factor, the effect of size can be computed by simple proportion as long as we are concerned with unmixed masses only. The problem may therefore be visualized as how to systematize the infinite variety of shapes into which a single lump of plastic material can be deformed.

In the manufacture of steel products, the primary process is plastic deformation by rolling, and the extremes to which this is carried are represented by sheets and rods. These primary products lead broadly to the main divisions of manufacture—plastic deformation and cutting. Casting is, from this point of view, a midway process which can produce only relatively compact pieces, whilst wire-drawing may be regarded as an extreme extension of the process of rolling rods.

All rod-like products may be regarded as cylinders, or combinations of cylinders. For the purpose of this investigation, it may initially be assumed to be of minor importance if the cross-sections are non-circular. The results, so far as they go, show that this assumption is justified, the ratio of the length to a single cross-dimension being the important attribute. If one cross-dimension is very many times that perpendicular to it, the part ceases to be rod-like and tends to become sheet-like. If sheets can also be viewed as cylinders there is immediately available a choice of parameters to which all experimental observations may be related. To do this is not so far-fetched as it sounds, as it entails no more than a corresponding assumption to that made in the case of rods, namely that if the cross-section (in this case the flat surface area) is very large compared with the length (now the thickness) it is relatively unimportant if the sheet is non-circular, thus departing from a true disc. It was therefore decided that the experimental material should consist basically of a series of cylinders of length/dia. ratio varying from approximately 0·02 to 20, *i.e.*, from flat discs to long rods.

With this material it was hoped to obtain fundamental knowledge, which, with the aid of experiments with a few compound shapes comprising a disc and a rod (rivet-shaped pieces), and with some mixtures, might be generalized to cover the whole range of scrap. This choice of material was also the form in which the required range and quantities could most conveniently be obtained, since flat or cylindrical articles of the most attenuated shape are directly produced by flat-rolling or drawing, with the minimum of cutting.

It has been tacitly assumed in the foregoing that the degree of attenuation of the ' unit lump ' of steel is, apart from size, the principal factor determining the ease with which a piece of scrap can be handled. This presumption appears quite natural, especially to those with experience of handling scrap. Objects like engine or gear parts, though of very complicated shape, are, from this point of view, compact and manageable pieces giving a high bulk density. Hollow objects like boxes or drums are also as manageable as solid pieces of the same external shape, and give a low bulk density only because of the enclosed empty space. If the obvious remedy of flattening is applied, they immediately fall into the category of thin discs for the purpose of this investigation. The most awkward types of scrap are long twisted rods or pipes, or thin bent sheets, with steel turnings as an extreme case of the former. The effect of twisting or bending rods and sheets must, however, be considered, and is accordingly included in this investigation.

The Problem of Bulk Handling

If it is fairly self-evident that ease of handling is principally a matter of degree of compactness, it may be asked why a somewhat lengthy series of laboratory experiments was necessary. It will be shown that the relationship between handling and compactness is very far from being a matter of simple proportion, but to be able to make use of the quantitative results of such experiments they must be designed with a clear connection with the actual processes of mechanical handling.

There might be little difficulty in the mere transport of scrap on a conveyer of some kind provided only that it is big enough. Wagon loads could be tipped directly on to such a conveyer and transported anywhere in a direct line. That, however, would contribute little or nothing to the solution of the real problem, which is how to get the scrap directly on to a charging machine without loading it piecemeal by a magnet crane.

It is probable that if this problem could be successfully solved, the existing type of charging machine could be replaced by a machine, perhaps with a reciprocating trough, from which portions of scrap would be swept off at every stroke. Such a machine is illustrated diagrammatically in Fig. 1, and it will be clear that if the empty end of the reciprocating trough could be loaded quickly enough there is, for practical purposes, no limit to the speed at which the machine could charge a furnace. The portion of trough to be filled at each stroke, however, would be of the same dimensions as the present type of charging pan, and it is evident that so long as steelmaking furnaces resemble the present types of open-hearth furnace and are charged through the doors, the ability to discharge portions of scrap from the main supply line into a receptacle of this size is the crux of the problem. Proposals to charge through the roof or through a doorless front of the furnace are primarily attempts to evade this problem, and have no merit from the point of view of furnace design.

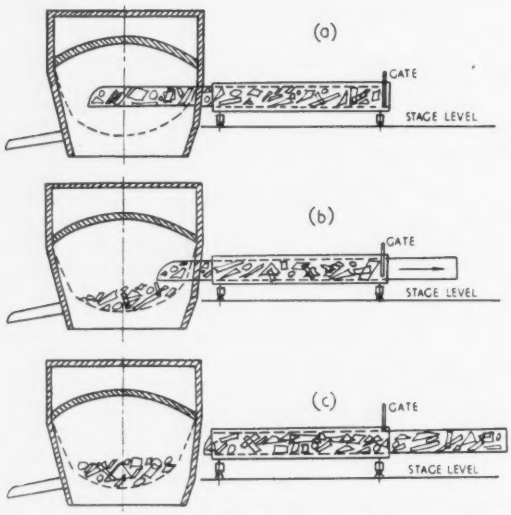


Fig. 1—Diagram of reciprocating charging machine: (*a*) Gate lowered at commencement of charging; (*b*) Charging stroke; (*c*) Gate raised for loading position

By itself, the mechanical conveyance of unprepared bought scrap would be useless because the scrap could only be dumped again on to a tangled heap, leaving unsolved the problem of getting it into the furnace. The primary difficulty is to get small lots to detach themselves readily from the mass. The question as to how they should be transported and whether they should be discharged directly into the charging receptacle or *via* bunkers or chutes can be left aside at this stage.

The most useful criterion for ease of handling would therefore appear to be some measure of the force required to separate two portions of a random heap of the scrap. Since gravity is obviously the most practicable force available, the type of experiment suggested is one in which measurement is made of the weight of the unsupported portion of the heap which can be sustained by the internal coherence of a cross-sectional face of the whole heap. In the actual experiment decided upon, use was made of a container with a flat bottom in which there was an opening ; the maximum width of the opening which could be bridged by the contents was determined. This gave a characteristic value for the breakdown force (or cohering stress) on the vertical sections above each edge of the aperture.

EXPERIMENTAL WORK

Scale Effect

This subject is ideally suited to small-scale research, since the effects to be investigated are dependent primarily on factors which are simple functions of the linear dimensions, and any secondary effects, such as surface roughness, can be safely neglected. The bulk density is the product of the density of the metal, which may be regarded as a constant for steel scrap, and the percentage volume of occupied space, which is an effect of random distribution. Provided that the distribution is unaffected during the filling of the container, the effect is subject to the laws of pure geometrical similarity. As regards the breakdown force of the heap, the condition for perfect similitude* is that the weight of the structure must bear the same ratio to the applied load for both model and original, and as the load is solely the weight of the structure itself, this condition is fulfilled as long as the prior condition regarding bulk density is also satisfied.

In addition to the scale effect, the effect of the method of filling the container had to be closely watched throughout the experiments. Any tendency for the pieces to orientate in one direction before they alight on the heap might affect the results, and frequent checks were made by slightly altering the method of dropping, thus ensuring that no such effect was taking place. All filling was done by hand by taking small quantities at a time and dropping them uniformly over the surface of the heap. Care was taken to avoid shaking and so disturbing the random distribution obtained in this way.

As it was conceivable that some scale effect might occur during the fall of the pieces, experiments were made to determine the percentage of occupied space of random heaps of similar cylinders of length/dia. ratio of 26, and ranging in linear dimensions from 1 to 13. Dissimilar metals were used, the pieces being cut from wire of various gauges.

As pieces had to be specially made for this experiment, it was desired to limit the number cut to each size, bearing in mind that it was only necessary to ascertain whether there is a significant difference between the percentages of occupied space for each size. The number of pieces in each measurement was of the same order, between the limits of 2000 and 7000, and measurements were made for each size of piece, using two containers, one having a diameter of about 2·5 times and the other about four times the length of the piece. The results, each of which is the mean of several fillings, are set out in Table I, and while these show that the quantities were too small to hide the effect of boundary conditions on the inside surface of the container, they confirm that no scale effect is detectable within the limit of accuracy required.

Material

For the measurements of breakdown force far larger

* *See* F. C. Johansen, " Research by Small-Scale Apparatus," *Proceedings of the Institution of Mechanical Engineers*, 1929, p. 181.

Table I

EXPERIMENT TO CONFIRM ABSENCE OF APPRECIABLE SCALE EFFECT

Relative Linear Dimensions	Material	Density of Material, g. c.c.	Vol. of Occupied Space, %	
			Narrow Container	Wide Container
1	Copper	8·9	16·7	18·0
5·8	Brass	8·5	16·6	18·5
10·2	Aluminium	2·6	16·7	18·2
13·1	Galvanized iron	7·8	16·9	17·8

quantities of material were required than were used in the scale-effect experiment, and it was necessary to obtain material from manufacturers equipped with quick-acting or stamping machines. The rods (cylinders with a length equal to or greater than the diameter) were cut from continuous lengths of steel wire, varying from needle wire of 0·018-in. dia. to wire of ½-in. dia., and the discs were mostly brass stampings, but included a large quantity of $\frac{7}{16}$-in. steel washers. For the compound pieces a very careful estimate was made of the minimum quantity required and two lots were machined from bar. The remaining lots consisted of a standard nail and a standard rivet.*

It would have been highly inconvenient, both in manufacture and in use, to prescribe that each shape should be of uniform volume, but as long as all the pieces of each shape are the same, this is of no importance in the case of homogeneous heaps, since there is no scale effect. All the results were multiplied by the appropriate scale factor in order to express them in terms of a uniform volume of 10 c.c., and they are finally presented more generally in terms of ratios. For mixtures the difficulty could not be so easily avoided, as pieces having the more extreme values of the ratio length/dia. naturally tended also to be those with the extreme scale factors.

Bulk-Density Measurements

Particulars of the series of cylinders are set out in Table II, together with the respective percentage volumes of occupied space in bulk. The latter value has been tabulated in place of true bulk density because metals of different density were used in the experiments, although the usual term ' bulk density ' has been used in a general sense when it is understood that steel scrap is being considered.

The measurements were made in wide containers and, as in the scale-effect experiment, are for random packing as obtained by dropping the pieces into the containers. The absolute accuracy of these measurements was again not high as no attempt was made to eliminate the effect of the boundary conditions, but it will be seen that the range of variation between the different pieces is so great in relation to the measurements themselves, that the accuracy was sufficient for the purpose. Individual readings for any one size of piece never varied by more than 4%, and generally by not more than $2\frac{1}{2}$%, showing that the average distribution for large quantities varies little, despite considerable local variations. Even this degree of variation was principally attributable to difficulty in judging the surface level of the heap.

It was assumed that the washers would take their place in the series as solid discs if the central holes were disregarded (just as hollow cylinders could have been used), because the average extent to which one such washer will penetrate another is negligible in a random heap.

These results are plotted in Fig. 4 against the length/dia. ratio on a logarithmic scale. On the same graph are plotted three elementary physical properties of the cylinders, the major linear dimension (*i.e.*, the length or diameter, whichever is greater), the surface area, and the sum of the moments of inertia about two mutually perpendicular axes. The relationship between these will be considered later in conjunction with the other experimental results.

The Aperture Test

The phenomenon of arching in loose materials packed in a container with an opening in the bottom is well known, and has been studied in connection with the flow of granular materials from bunkers. The whole subject has been excellently reviewed by Brown and Hawksley,‡ who include a bibliography in their paper. They suggest that the free flow of granular materials is similar to flow under shearing forces in that particles tend to move in groups, the boundaries between which resemble lines of slip. The experiments to be described were first suggested by the actual process which it was desired to represent, namely the discharge or detachment of small portions of a heap ; but some hypothesis as to the mechanism by which this takes place was necessary in order to establish a basis on which quantitative evaluation could be made.

Preliminary experiments showed that there was a wide variation in the ability of heaps of cylinders of different length/dia. ratio to bridge a gap in the bottom of a rectangular container. Long thin rods (in the form of needle blanks), for instance, form a heap so

* Special thanks are due to Messrs. Guest, Keen and Nettlefold who kindly supplied most of the steel material free of charge for the purpose of this research. Some measurements were also made with a quantity of razor blade punchings kindly supplied by Mr. F. C. Horster of Sheffield, to which reference will be made ; these were not flat.

Table II

SERIES OF CYLINDERS WITH THEIR BULK DENSITIES

Note—The true bulk density is the product of the percentage volume of occupied space and the density of the material.

Actual Dimensions, in.	Ratio length/dia.	Scale Factor	Equivalent Dimensions for 10 c.c. vol., cm.		Vol. of Occupied Space, %
			Length	Diameter	
Discs					
$1\frac{3}{4}\times0{\cdot}036$	0·021	1·92	0·17	8·5	38·7
$\frac{7}{8}\times0{\cdot}048$	0·055	2·78	0·34	6·2	48·6
†$\frac{7}{16}\times0{\cdot}031$	0·071	5·07	0·40	5·6	47·2
$\frac{1}{2}\times0{\cdot}128$	0·256	2·92	0·94	3·7	55·7
$\frac{5}{8}\times0{\cdot}192$	0·307	2·07	1·06	3·5	64·3
Rods					
$\frac{1}{2}\times0{\cdot}45$	1·11	1·98	2·5	2·26	61·8
$\frac{1}{2}\times0{\cdot}33$	1·52	2·42	3·1	2·04	61·8
$\frac{1}{2}\times0{\cdot}162$	3·09	4·11	4·9	1·60	56·2
$\frac{1}{2}\times0{\cdot}125$	4·0	4·65	5·9	1·47	52·2
$\frac{1}{2}\times0{\cdot}062$	8·0	7·38	9·4	1·17	43·4
$\frac{3}{4}\times0{\cdot}062$	12·0	6·42	12·2	1·02	30·0
$1{\cdot}031\times0{\cdot}062$	16·5	5·77	15·1	0·92	26·8
$\frac{1}{2}\times0{\cdot}028$	17·9	12·4	15·7	0·88	26·8
$1{\cdot}64\times0{\cdot}063$	26·0	4·82	20·5	0·79	17·4
$\frac{1}{2}\times0{\cdot}018$	27·6	16·8	21·3	0·77	19·4

† Washers with a central hole $\frac{7}{16}$ in. dia. assumed to be occupied space.

‡ R. L. Brown and P. G. W. Hawksley, " The Internal Flow of Granular Masses," *Fuel in Science and Practice*, 1947, vol. 26, p. 159.

closely entangled that enormous quantities of them can be suspended by arching, whereas cylinders with a 1/1 ratio flow very readily through a comparatively narrow opening. This difference in behaviour was clearly a direct manifestation of the property which it was desired to investigate. It was further observed in many cases that, after collapse had taken place, more or less vertical walls were left above each edge of the gap, although collapse takes place locally along lines of slip inclined at an angle to the vertical. It therefore seemed possible that if the maximum breakdown or shearing force which would sustain the weight of suspended material were evaluated on the basis of a unit area of the vertical section above the edge of the gap or aperture, this would give a figure characteristic of the heap.

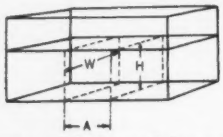


Fig. 2—Diagram of box used for aperture test

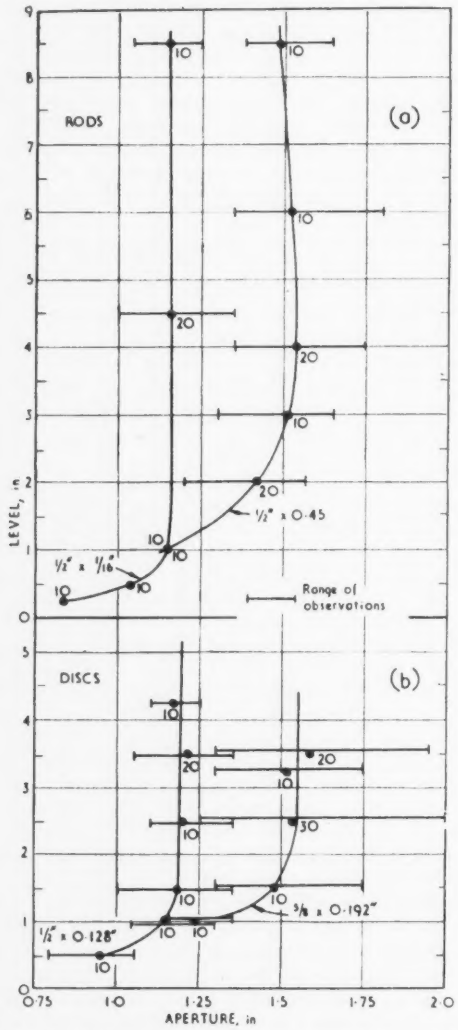


Fig. 3—Typical results of aperture test for quantities of (*a*) rods, and (*b*) discs. The figures are the numbers of observations made at each level

Figure 2 shows diagrammatically the container (which had glass sides for observation) with a central aperture in the floor. The aperture extends the full width of the container. If the friction of the sides is neglected, the area of the vertical faces from which the suspended mass is supported is $2H.W$ where H is the height of the heap and W is the width of the container. If the density of the metal is ρ and the voidage f, the weight of the suspended column is

$$\rho(1-f)H.A.W$$

where A is the width of the aperture. The shear force per unit area is therefore

$$\frac{\rho(1-f)H.A.W}{2H.W} = \tfrac{1}{2}\rho(1-f).A \quad \ldots\ldots\ldots\ldots(1)$$

Since ρ and f are constant for any particular heap, it follows that A should be independent of the width of the container, and of the height of the heap above the aperture.

A container of this description was constructed with a floor consisting of movable steel plates which could be slid back underneath each other. In this way the aperture could be gradually opened with the minimum disturbance of the pieces resting on the bottom. When the container was filled to a prescribed level H, the aperture was opened until the suspended column collapsed and fell through. For the same material the maximum aperture obtained in this way at any given level varied greatly, due to the fortuitous conditions of packing at the supporting faces, and also to secondary effects occurring between the partial breakdown and reforming of arches. The averages of successive sets of ten tests, however, show a comparatively small variation, and by taking a sufficient number of tests a mean value can be obtained which can be repeated fairly closely. Series of tests

Table III

RESULTS OF APERTURE TESTS FOR SIMPLE CYLINDERS

Ratio length/dia.	Scale Factor	Equivalent Dimensions for 10 c.c. vol., cm.		Equivalent Aperture for 10 c.c. vol., cm.
		Length	Diameter	
Discs				
0·055	2·78	0·34	6·2	32·5
0·071	5·07	0·40	5·6	42·7
0·256	2·92	0·94	3·7	8·9
0·307	2·07	1·06	3·5	8·15
Rods				
1·11	1·98	2·5	2·26	7·72
1·52	2·42	3·1	2·04	7·43
3·09	4·11	4·9	1·60	10·6
4·0	4·65	5·9	1·47	12·1
8·0	7·38	9·4	1·17	20·4
17·9	12·4	15·7	0·88	113·4
27·6	16·8	21·3	0·77	299

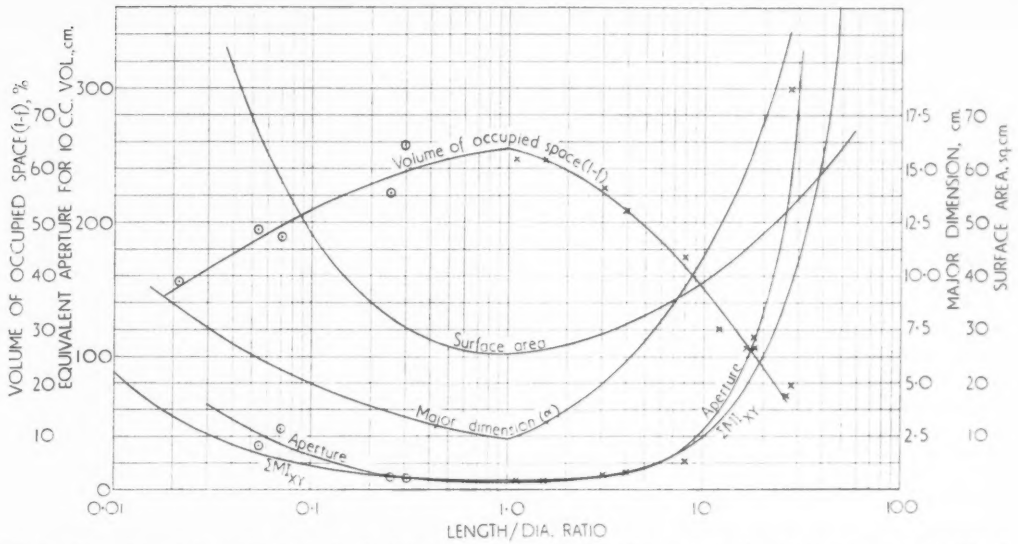


Fig. 4—Experimental results and physical data related to length diameter ratio, plotted on a logarithmic scale

with different heaps consisting respectively of simple and compound cylindrical shapes showed that, above a certain level, the mean aperture at the moment of breakdown was in fact independent of the level, as required by the foregoing hypothesis. This independence is shown by Fig. 3, which gives typical series of test results for a heap of rods and a heap of discs respectively.

Despite the complexity of the mechanism of breakdown (as, for instance, when an arch formed of rods partially falls in and gives two abutting faces of vertically disposed rods), it appears that, if the averages of large numbers of experiments are taken, the hypothesis is valid ; and the maximum aperture was determined in this way for heaps of every shape of piece. To reduce the results to a common basis, the equivalent values for pieces of uniform volume of 10 c.c. were worked out, the actual aperture observed being multiplied by the scale factor appropriate to each piece. The results are given in Table III, and are plotted in Fig. 4.* It will be observed that they give a series of values with a consistent trend again clearly related to the shape of the piece.

* The experimental results are only summarized here, but are recorded in full in Paper PE/D 50/49 of the British Iron and Steel Research Association.

Compound Pieces and Mixtures

Measurements of percentage volume of occupied space and the aperture test were carried out on four heaps of compound pieces, each representing different combinations of discs and rods. The pieces are

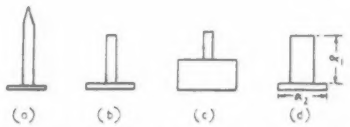


Fig. 5—Compound pieces (*see also* Table IV)

illustrated in Fig. 5, and will be seen to give a good range of combinations. Dimensional data for the pieces, and the results of the tests, are given in Table IV.

Volumes of occupied space and aperture measurements are in all cases lower than for either of the simple cylinders making up the compound shape, estimating the latter from the curves through the experimental points in Fig. 4. This means that such compound shapes would be easier to handle mechanically in bulk than the simple shapes, but that they would give a lower bulk density.

Table IV

DATA AND TEST RESULTS FOR COMPOUND PIECES

Piece	Ratio length dia.		Scale factor	Equivalent Dimensions,† cm.		Vol. of Occupied Space, v_o	Equivalent aperture for 10 c.c. vol., cm.
	Disc portion	Rod portion		a_1	a_2		
Clout nails (Fig. 5*a*)	0·077	8·5	4·37	7·4	3·5	27·5	23
Thin head, thin shank (Fig. 5*b*)	0·132	4·85	3·37	3·8	4·3	31·0	12·5
Thick head, thin shank (Fig. 5*c*)	0·506	2·28	2·28	1·5	2·9	50·3	8·1
Tinman's rivets (Fig. 5*d*)	0·124	2·76	2·76	3·0	3·3	43·3	9·8

† Equivalent greatest dimensions of complementary portions for 10 c.c. total vol.

Table V

DATA AND TEST RESULTS FOR A MIXTURE

Discs : $\frac{7}{8}$ in. × 0·048 in. ; scale factor 2·78
Rods : $\frac{1}{2}$ in. × 0·33 in. ; scale factor 2·42

	Discs	Rods	Mixture
Vol. of occupied space, %	48·6	66·7	48·3
Equivalent aperture for 10 c.c.	32·5	7·43	13·2

Reference has already been made to the difficulty of obtaining a range of mixtures of which the constituents have approximately the same scale factor. In practice, of course, mixtures of pieces of widely differing size will frequently occur, but the presence of small pieces in amongst large pieces obviously introduces a factor which is independent of shape. Generally, the admixture of pieces sensibly smaller than the limiting dimensions determined for any category of scrap will always be advantageous by increasing the percentage of occupied space without increasing the breakdown force. This follows from the fact that similar cylinders, for instance, of one size can lie in the spaces between those of a considerably greater size.

One convenient pair of cylinders for a mixed heap with a scale factor of the same order exists, however, in the $\frac{7}{8}$-in. discs and the $\frac{1}{2}$-in. × 0·33-in. rods ; the data and experimental results for this mixture are given in Table V.

It will be seen that the results for the mixture are very much nearer the lower of the two values, for both tests, of the component pieces. This means that the bulk density of such a mixture will be similar to that of the worst element of the mixture, but that the ability to handle the more difficult element would be greatly improved by admixture of pieces of a more favourable shape.

THEORETICAL CO-ORDINATION OF RESULTS

The curves in Fig. 4 indicate that the results of both the bulk-density and aperture tests are related in some direct way to the linear proportions of the pieces. It is now proposed to put forward a simple theory to account for this relationship. The theory provides a basis for a more generalized presentation of the experimental results for the simple cylinders, and also enables the results for the compound shapes and mixtures to be explained in a manner affording a useful basis for the practical problem of scrap preparation for mechanical handling in bulk.

Consider first the random packing of a heap of cylinders. To obtain the maximum possible percentage of occupied space, the cylinders would have to lie in long parallel rows with the flat surfaces together. In the aggregate therefore, cylinders of any length/dia. ratio would assume the form of long rods all lying in one direction, and the bulk density would be independent of the length/dia. ratio. The essential feature which distinguishes a random packing is that the cylinders do not lie parallel to each other, but point in all directions.

Figure 6 shows two pairs of cylinders lying at an angle to each other, which may therefore be regarded as the typical condition in a random packing. The pair *a* have the principal dimensions (length and diameter) of the same order ; pair *b* have one principal dimension very much greater than the other. Irrespective of whether the greater dimension is the length or the diameter, voidage in the parallelogram occupied by each piece will be the same whether the diagram represents two discs on edge or two rods on their sides. It will be convenient therefore to refer to the ratio of the major and minor dimensions as the ' shape-ratio ' as a general expression of the degree of attenuation.

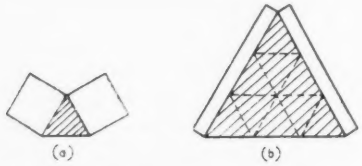


Fig. 6—Typical condition in a random packing of cylinders

It can easily be shown by geometry that the area between the two pieces increases as the square of the major dimension. It is also apparent that the number of other pieces which can penetrate between the two pieces shown, and hence the number of intersecting triangles, will also increase as some function of the major dimension. If we consider a unit depth of a heap composed of pieces so disposed, the volume occupied by the solid will increase in the case of rods and decrease in the case of discs, since there will be more of the former and less of the latter lying along each other as the major dimension is increased.

In Fig. 7 the voidage f is plotted against the major dimension. To render the values independent of absolute size, the major dimension is expressed in the form of a ratio. If instead of taking a standard volume of 10 c.c., we call the volume of the cylinder v, the minimum value of the major dimension is obtained when the length equals the diameter (*i.e.*, with a shape-ratio of unity), and is equal to $1{\cdot}08v^{\frac{1}{3}}$. In Fig. 7, therefore, the major dimension is plotted as the ratio

$$\frac{\alpha}{1{\cdot}08v^{\frac{1}{3}}}$$

Figure 7 shows that, within the range of the graph covered by the discs, there is no significant divergence of the points for discs and for rods. The probable reason for this can readily be observed in actual heaps

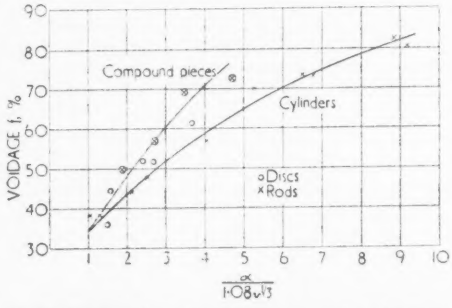


Fig. 7—Relationship of voidage to major dimensions

of flat discs, where an increasing proportion of discs tend to lie with their flat surfaces together as the shape-ratio increases. The graph suggests that this factor causes an increase in solid volume for each triangle that is about the same as that for rods. If the voidage is plotted against total surface area two diverging curves are obtained, one for discs and one for rods.

If this conception is correct, the factors affecting the volume of occupied space are :

(1) The increasing triangular spaces between pairs of pieces per unit volume of solid as the shape-ratio increases, which effect would be proportional to the major dimension raised to some power between 1 and 2

(2) The opposing effect of the increasing degree of interpenetration or overlapping of the triangular space with increase of shape-ratio, which may also reasonably be supposed to be proportional to the major dimension raised to some power greater than unity.

The net result must therefore be that the voidage increases as some fractional power of the major dimension ; and it is found that if the results are plotted to the power $\frac{1}{3}$, *i.e.*, the cube root of the major dimension, a linear relationship is obtained, as in Fig. 8.

The general conclusion may therefore be drawn that the proportion of occupied space in random heaps composed of similar pieces of the same volume but of different shape-ratio is proportional to the cube root of the major dimension of the piece. Though not a precise law, and true only for a limited range of shape-ratio (though for a range not so far short of the limit of rigidity), this conclusion is a generalization of great practical value in dealing with so complex a problem as a scrap heap.

The compound pieces fit very well into the theory if the sum of the major dimensions of the component portions is used. At the value

$$\sqrt[3]{\frac{\alpha_1 + \alpha_2}{1 \cdot 08\sqrt{3}}} = 1$$

the curves intersect, since at this point α_1 or α_2 must equal zero, and the piece becomes a simple cylinder. The higher values are probably accounted for by the fact that less interpenetration of the pieces into the intermediate triangles is possible, because of the restriction in two mutually perpendicular directions on the position occupied by each piece.

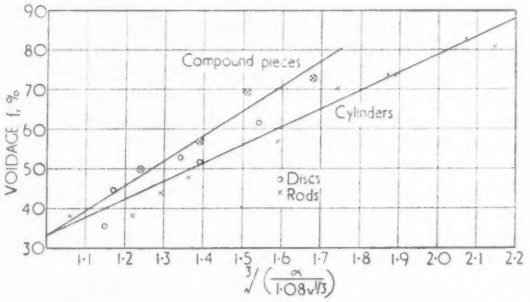


Fig. 8—Relationship of voidage to cube root of major dimensions

Figure 4 suggests that the results of the aperture test bear some relation to the sum of the moments of inertia about a longitudinal and a cross axis. If they are plotted on this basis, however, two converging lines are obtained for discs and rods : as is also the case if the results are plotted on a basis of surface area, or indeed on the basis of any function comprising the addition of the linear dimensions or their powers. Consideration of the problem suggested the theory that when breakdown takes place it is of the nature of failure by shear across the slip faces, wherever these may occur ; and, as has already been shown, the broad hypothesis that the shear force may be calculated on the vertical face above the edges of the aperture justifies the use of the aperture test, as a characteristic of that property of the mass that it is desired to measure. The shear force depends upon the weight of material supported immediately before breakdown, and thus upon the width of the aperture A, the density of the material ρ, and the voidage f. The shear resistance may also be dependent on ρ and f.

It appears reasonable to suppose initially that the attainable width of aperture A, will depend on the major dimension of the piece α ; very long pieces will bridge a greater aperture than very short pieces. We therefore have, as a partial statement

$$A \propto \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The shear or cohesive resistance of the mass depends also on the ability of each piece to support other pieces at the outer end, cantilever fashion, by the pressure of other pieces resting upon it at the inner end. Pieces with major and minor dimensions equal can neither support, nor be held down by, even one

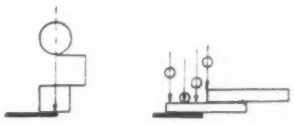


Fig. 9—Cohesion obtained from pressure of overlying pieces

other piece. Pieces with the major dimension several times the minor dimension can, however, support and be held down by the pressure of several other pieces vertically above, and it may thus be supposed additionally that the shear resistance is proportional to the ratio of the major and minor dimensions. This is illustrated in Fig. 9 ; but it should be borne in mind that the same principle holds across any plane of slip. We therefore have additionally

$$\text{Shear resistance} \propto \frac{\alpha}{\beta \cdot \rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The density ρ, is introduced since the pressure holding down the supporting pieces is dependent upon it in the same way as is the weight supported.

At the point of breakdown, the shear resistance and shear force are equal ; hence, using the expression for shear force given in equation (1), and combining the statements of proportionality (2) and (3), we have

$$\tfrac{1}{2}\rho(1 - f).A \propto \frac{\alpha^2}{\beta \cdot \rho}$$

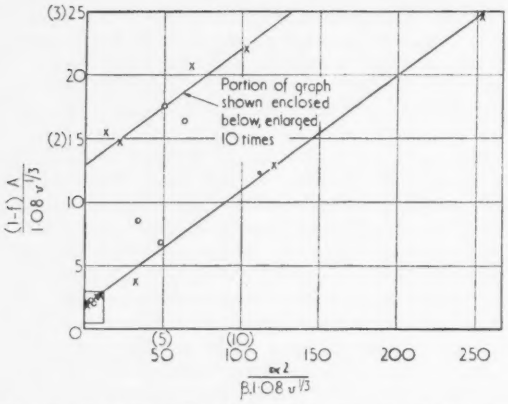


Fig. 10—Relationship of aperture test to major and minor dimensions

Expressing the linear dimensions as before in a generalized form for pieces of all volumes, this becomes

$$\frac{(1-f).A}{1{\cdot}08v^{\frac{1}{3}}} \propto \frac{\alpha^2}{\beta \times 1{\cdot}08v^{\frac{1}{3}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The results of the aperture test are plotted in Fig. 10 as a graph of the left-hand quantity in this expression against the right-hand quantity, and give a very good linear relationship.

This theory does not offer a complete explanation of the results of the aperture test. The question arises whether, if the density ρ is introduced into the proportional relationship (3), the term $(1-f)$ should also be included, as it affects both supporting and supported weight equally. However, the density of the metal has no effect on the pattern of contacts between the pieces, and, as an experiment with aluminium pieces proved, cancels out by affecting shear force and shear resistance equally, whereas the voidage is intrinsically associated with the pattern of contacts. Moreover it can be varied independently of the shape of piece by controlled distribution.

Some attempts were made to ascertain the effect of forced distribution on the aperture test by shaking down, but it was found that the weight of material was too great to enable this to be done with the apparatus available. Supposing, however, that a heap of rods with a high length/dia. ratio was built up by orientating them, magnetically or otherwise, with their axes parallel, the volume of occupied space could be increased to the maximum possible for a heap of cylinders of any proportions, while at the same time no piece would lie across another. For such a heap it might be expected that the aperture would be a minimum. It is possible to imagine other special arrangements, for example with alternate layers orientated at right-angles to each other, which might give larger apertures, but from general observation of the characteristics of the random heaps it would appear that the random condition giving a high degree of criss-crossing of the pieces must give the greatest apertures.

If, in Fig. 10, the value of $A\ 1{\cdot}08v^{\frac{1}{3}}$ were plotted, omitting the voidage, a curve would be obtained, and it is scarcely possible that this could be due to the admitted uncertainty regarding the accuracy of the point at the extreme right of the graph.

The value for the washers with the central hole lies well off the straight line of Fig. 10, although this value was determined from a very large number of tests. No ready explanation of this is apparent.

The results of the aperture test on the compound pieces can be explained satisfactorily on the above theory. The values for $(1-f).A$ are mostly at or slightly below the lowest value given by Fig. 10. In regard to the number of pieces which can lie across each other, the relevant ratio is that between the greatest length and greatest diameter (or *vice versa*) of the piece as a whole. Reference to Fig. 5 shows that in this respect three of the pieces are very nearly equivalent to a cylinder with a length/dia. ratio of unity, and accordingly fall at the extreme left of the graph. In the case of the clout nails the value obtained for the aperture test is in good agreement with the value on the graph for the equivalent α/β.

BENT PIECES

It is obviously important to know what the effect of bending the cylinders may be, but to obtain a quantity of uniformly bent cylinders presents difficulties. However, two experiments were carried out which serve to confirm a conclusion which can be fairly confidently drawn by deduction. This conclusion is that bending which encloses any space thereby made less accessible to neighbouring pieces will cause the piece to behave, in respect of the properties under consideration, as if the enclosed space were wholly or partly solid. A mass of rods coiled in the form of helical springs, for instance, would pack and flow like solid cylinders of the same external dimensions. On the other hand a mass of rods bent once at right angles might be expected to give practically the same results as if they were straight.

The last-mentioned conclusion was the subject of a direct test, a quantity of the $\frac{1}{2}$-in. $\times$ $\frac{1}{16}$-in. rods being bent through a right-angle midway along their length. The volume of occupied space of the bent pieces was practically the same as that of the straight pieces, while no difference was apparent in the maximum aperture in the aperture test. Experiments were also made with the razor-blade punchings referred to on p. 455, the results on which, together with those relating to the bent rods, are given in Table VI.

The razor-blade punchings were not quite uniform, so average dimensions are given. As a result of the punching process they were all slightly dished. The space enclosed by the dishing can only be penetrated by adjacent pieces lying with their respective concave and convex surfaces together. It was therefore to be expected that both the bulk density and the shear force should be considerably less than for the flat pieces, and this proved to be the case. Flat discs of the same diameter and thickness would give a percentage volume of occupied space of 42 (Fig. 7), whereas the dished pieces give only 26·4%. The shear force value for the flat discs calculated from Fig. 10 would be 142 g./sq. cm., compared with the

Table VI

DATA AND TEST RESULTS FOR BENT PIECES

Shape	Scale Factor	Equivalent Dimensions for 10 c.c. vol., cm.			Vol. of Occupied Space, %	Equivalent Aperture for 10 c.c.
		α	β	β_1		
(*A*) Bent rod, length/dia. = 8	7·38	9·4	1·17	...	43·0	20·4
(*B*) Bent disc, length/dia. = 0·023	13·6	8·2	0·19	1·23	26·4	55·9

Shape *A* Shape *B*

actual value of 57·2 g./sq. cm. The latter, however, as would also be expected, is rather above the value for the dimensional ratio α/β_1 (using the notation of Table VI) of the piece as a whole, namely 41 g./sq. cm., since an appreciable proportion of the pieces do actually lie within each other.

PRACTICAL CONCLUSIONS

Selection and Preparation of Scrap for Bulk Handling

The results of laboratory experiments such as those described are useful as a practical guide to the selection and preparation of scrap for bulk handling to the extent to which they show very strong demarcations in behaviour. This, however, they do in a very striking manner, as a glance at the aperture curve in Fig. 4 shows. There is a comparatively well-defined range of the ratio length/dia. within which plain cylindrical pieces can be satisfactorily handled. Outside this range their ability to hold up increases with surprising rapidity to what would be an almost unimaginable extent were it not for the fact that the limit of rigidity intervenes.

Another important fact which emerges, contrary perhaps to what might have been expected, is that bent and twisted pieces will not be more difficult to handle than straight pieces, at least when large quantities are being dealt with, though the bulk density obtainable will generally be lower.

It is also noteworthy that what have been called compound pieces (typifying a common kind of scrap, such as flanges with bits of piping attached) will be easier to handle than if they were separated into their component pieces, though they will give a lower bulk density.

It must therefore be recognized that the selection of scrap for mechanical feeding to a high-speed charging machine will not necessarily improve the bulk density. This is a very important consideration, and shows that the whole problem must be considered in all its aspects and not piecemeal. It means that a bulk-handling system might even be a failure if used in conjunction with existing types of charging machine, because in some circumstances the average pan density could at times be reduced to a point at which the charger would fall behind the demands of the furnace. Take, for example, a heap of hollow drums. These might be of ideal proportions for feeding rapidly from a conveyor, but would give a poor rate of charging with the normal type of charger. If, however, they were flattened to give a good bulk density they could, if in considerable quantities, become impossible to discharge mechanically on to a quick-acting charging machine.

The use of bundling presses, on the other hand, is right from both points of view, and there is no doubt that this is the best way of dealing with all scrap except that of heavy section.

Faced with a miscellaneous lot of mixed scrap, how would it have to be sorted for bulk handling? It is assumed that all heavy pieces accord strictly with existing specifications, *i.e.*, that no individual piece exceeds the limits of 'furnace size.' The criterion for the segregation of all except small pieces is the ratio of the major and minor overall dimensions, for which the limit would probably have to be set at not more than 6 1. By 'major' and 'minor' dimensions are meant the maximum and minimum of the overall dimensions in the three natural axes of the piece (length, breadth, and depth). For convenience this ratio is called the 'shape-ratio.'

Now it will be seen that a piece of **H**-section girder 5 ft. long by not less than 1 ft. wide and deep would fall within this requirement, whereas a quantity of loose stakes, or a piece of piping 4 ft. long by 1 in. width (or diameter) would not. With individual pan loading, as at present, the piece of girder, typical of ship-breaking scrap, is disliked because of its low bulk density in a pan, whereas the stakes, if laid (with a great deal of expensive hand trimming) neatly along a pan, would give a very good bulk density. But it would require much more expensive methods to reduce the girder to smaller dimensions than to bundle the stakes; so that it appears that scrap preparation might be a much more practicable and economical proposition for a wholly mechanized scrap-charging system than it can be when its only object is to get a greater bulk density by individual pan-loading methods.

The principal difficulty that seems to arise is the prevalence of scrap in the form of pieces of plate. According to the suggested rule, a piece of plate 1 in. thick must not exceed a length or width of 6 in. Obviously there must also be a limit of absolute size, below which any shape is acceptable, and it would probably be satisfactory to fix this at a figure such as a maximum overall dimension of 3 ft., which would overcome this difficulty to a large extent. The bed of material on a conveyor would be kept relatively thin as compared with the levels necessary in the aperture experiments to give the

maximum recorded aperture. It would only be in the case of plate- or strip-mill scrap that large quantities of plates would be fed together on to a conveyor unmixed with other material. In such cases the experiments with a mixture show that difficulty could be avoided if it were possible to mix a certain proportion of, for example, bloom ends with it. Failing this, care would have to be taken to limit the depth of plate scrap on the conveyor to a very low figure.

Sorting on this basis would throw out all long and thin pieces, as well as plate, above a certain size. It might prove to be a tedious and expensive process if applied to truckloads of scrap to existing specifications, but the installation of bulk-handling equipment on any large scale would be facilitated by the introduction of new specifications on the lines here indicated, so that the sorting could to a large extent be done before the scrap of different kinds is mixed at source.

The important question of the limiting dimension, below which pieces of any proportions would be acceptable, would have to be settled in closer relation to the actual arrangement envisaged for the handling plant. It is probable that these results would be useful in connection with many kinds of handling operation besides a complete bulk-handling system.

Experiments might be made, for instance, by discharging scrap on to a steeply inclined chute, and thence into a trough at the bottom, representing either the unloaded end of a reciprocating charging machine of the type shown in Fig. 1, or an ordinary charging pan. The chute would perform an important function, not achieved with a magnet crane, in orientating the pieces in the direction of the axis of the trough. Something might be done on these lines to develop a mechanical pan trimmer in association with existing pan-loading methods, and this possibility is envisaged in Fig. 11.

Nothing as yet has been said about the preparation of scrap rejected as unsuitable for bulk handling, except that it will consist largely of pieces of relatively small cross-section, such as lengths of piping or rod, wire and strip of all kinds, and large pieces of sheeting ; in fact all the thin tangled stuff that would be likely to get caught up in any handling apparatus, however carefully designed ; quite apart from the difficulties it would cause at the point of discharge.

Material of this kind is generally suitable for baling when using a big enough press, and an essential part of any plant designed for bulk handling of scrap should be a very big press designed to produce the largest bundles that can be got through the furnace doors. These would be well within the prescribed limiting shape-ratio.

The principal type of rejected scrap which could not be bundled would be large pieces of thick plate. These could be handled efficiently by magnet crane, with other rejected scrap, or be gas cut, in which case the bulk density also would be improved.

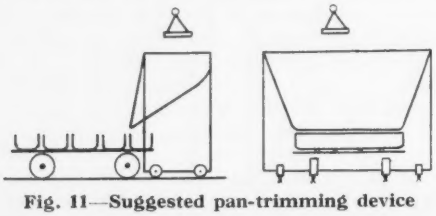


Fig. 11—Suggested pan-trimming device

Considering again mill scrap, bloom ends at present frequently exceed both the suggested limiting dimensional ratio and maximum dimension. It should not be difficult to shear these into shorter lengths while hot, at source ; and the gain from being able to handle all mill scrap in bulk would make it well worth while.

CONCLUSIONS

The conclusions to be drawn from this work have been set down in full in the last section, but for convenience they are briefly summarized and enumerated below :

(1) To ensure that scrap in bulk can be successfully fed, without hand trimming, from a chute to a charging pan or a charging machine, no individual piece must either (*a*) exceed a certain maximum overall dimension to be determined for a particular type of plant, but probably of the order of 3 ft., or (*b*), if between this limit and maximum furnace size, exceed a certain shape-ratio, about six, between the maximum and minimum overall dimensions in the three normal axes of the piece.

(2) Segregation on this basis will not necessarily give the maximum attainable bulk densities. On the other hand, quick-acting charging machines, of the reciprocating type suggested in the paper, or of some other kind, with their possibilities of greatly increasing the rate of furnace charging, would not be successful without new types of mechanical handling plant.

(3) Scrap preparation by bundling presses gives both ease of handling and good bulk density. The introduction of new methods of mechanical handling might greatly increase the economic advantage to be gained by bundling, and the installation of bundling presses of maximum capacity would be an essential feature of such methods of bulk handling.

(4) Scrap rejected by the application of conclusion (1) would consist largely of material which could be bundled in a press of maximum capacity capable of delivering bundles within ' furnace size.' The principal exception would be large pieces of heavy plate which would have to be handled separately by magnet crane or cut into smaller sizes, in which case the bulk density would also be improved.

(5) In order to handle mill scrap in bulk some additional shearing would be necessary to ensure that no piece of plate, strip, or bar exceeded the permitted maximum overall dimension given in conclusion (1*a*). Arrangements could be made to do this while hot, at the source of the scrap.

(6) Folding is twice as effective as cutting in dealing with strip or sheet scrap, both in obtaining high bulk density and ease of handling. Large bundling presses are the most practicable method of folding.

(7) If considerable quantities of plate scrap have to be handled in bulk it would be advantageous to mix them with bar material or bloom ends. Failing this, the depth of plate scrap on the conveyor would have to be kept very low.

IRON AND STEELWORKS ENGINEERING

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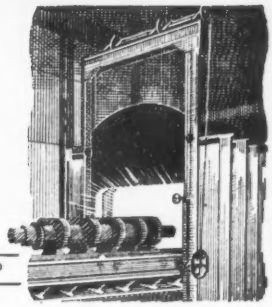

Heavy Forging Manipulators

By A. V. Flinn, M.I.Mech.E, M.I.Struct.E.

SYNOPSIS

A description is given of rigid-type forging manipulators, which can be used to handle most articles produced in the forge. The machines are classified as ' low,' ' semi-high,' and ' high,' according to the height of the peel centre-line from the shop floor-level. Low-type manipulators are those up to 6000 lb. capacity, whilst semi-high and high machines have capacities in the range 10,000–40,000 lb.

The four types of manipulator are described, *viz.*, straight-line type ; straight-line revolving type ; straight-line bridge type, and revolving-trolley bridge type. These may have three or more of the following seven motions : Tongs gripping, peel rotating, hoisting, levelling, slewing, traversing, and bridge travelling ; a brief description of these motions is given.

Mechanical handling has been incorporated in many shops, particularly in America, and some plant lay-outs are suggested. Figures showing outputs before and after the installation of manipulators prove their value.

ONE of the foremost labour-saving machines is the forging manipulator—a machine which is capable, under nearly all conditions, of handling the material which is to be forged by the press or hammer. It considerably reduces the number of men and the amount of heavy manual work, and minimizes the danger of major accidents at the press or hammer. Manipulators are used for all kinds of forgings, such as axles, die blocks, heavy shafting, and most kinds of commercial work ; they are also being used for the blooming of ingots in plants where the production is not sufficient to justify the purchase of a blooming mill.

TYPES OF MACHINE

General

For light work such as axles, die blocks, wheels, and special light drawing, the ' low '-type machine is most suitable, and is generally made in capacities up to 6000 lb. Machines above this capacity are of the ' semi-high ' and ' high ' types, and follow the same basic principles and construction as the low type, but differ considerably in detail.

Manipulators as at present being made may be divided into two classes, rigid and mobile ; the former run on fixed rails, whereas the latter do not. The machines described later are all of the rigid type ; this type of machine is necessary to deal with most present-day forge work, particularly with the large and heavy class of forgings.

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Low Straight-Line Trolley Type

This is the simplest type of manipulator ; it runs on rails laid in the floor in front or behind the press or hammer. It is strictly limited to a backward or forward motion of the trolley, and all work has to be presented to the hammer or press by external means. The machine is comparatively easy to make, is rigid in construction, and gives little trouble with maintenance.

In a number of cases, such as when making axles, it is necessary to have a small amount of lateral motion. A skewing motion is sometimes introduced which moves the back or fulcrum end of the peel a few degrees laterally, and thus permits the use of double- or triple-notched die blocks. These added motions do not give the best results for axle work, however, because the two outer notches in the dies have to be placed angularly to the centre notch, or, if there are only two notches, they must be at an angle to each other.

Figure 1 shows, in outline, an early low straight-line trolley-type machine which was used for forging blocks and cheeses. It had five motions, *viz.*, hoisting, levelling, tong gripping, tong revolving, and traverse.

As an alternative to the trolley having a skewing motion, a straight-line machine has been provided with a hydraulically actuated bridge which has a

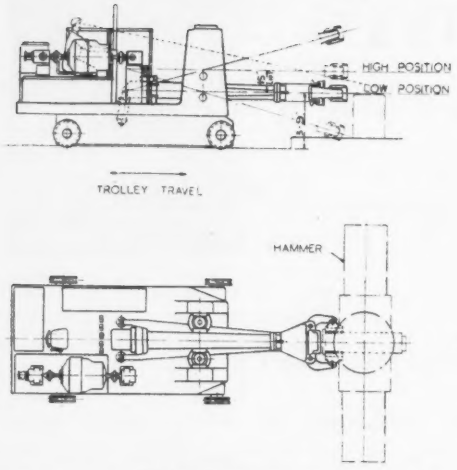


Fig. 1—Low straight-line-type manipulator of 6000 lb. capacity

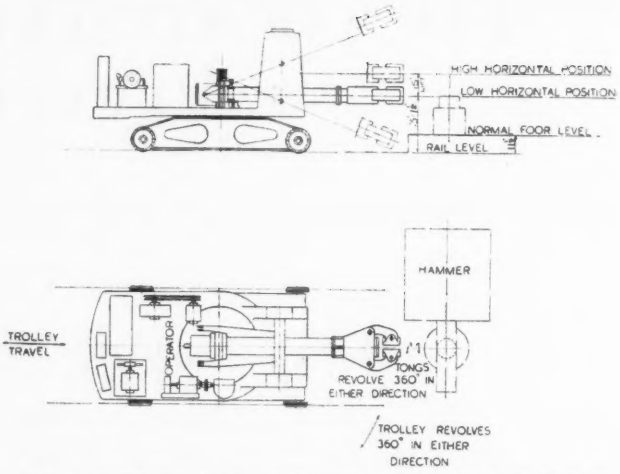


Fig. 2—Low revolving-trolley-type manipulator of 2000 lb. capacity

movement of 9 in. on each side of the hammer centre-line, corresponding to the distance between the centres of the notched die blocks.

Low Straight-Line Revolving Type

Most manipulators are now provided with a full-circle revolving motion. This added motion not only gives much greater freedom of movement at the press or hammer, but also gives a much greater range of usefulness in transferring the work from the conveyor table and in unloading after forging is completed. However, the introduction of a turntable into the machine increases its height, and this may necessitate a pit being sunk below the normal level of the shop floor in order to accommodate the increased height. Figure 2 illustrates the low straight-line revolving-type machine.

Low Straight-Line Bridge Type

Originally, manipulators were seldom used for charging or drawing in or out of furnaces, although of recent years they have increasingly been used for this work. As several furnaces are usually in use, an additional motion, bridge travel, is introduced in this type of machine (Fig. 3). The bridge motion makes a skewing motion unnecessary. Since the peel is between the girders, the height of the centre of the tong head can be kept low, thus keeping a convenient relationship between the floor-line and the top of the die, and the peel can easily reach the floor-line without danger of interference with other parts of the machine.

Low Revolving-Trolley Bridge Type

In order to obtain the complete freedom desired in

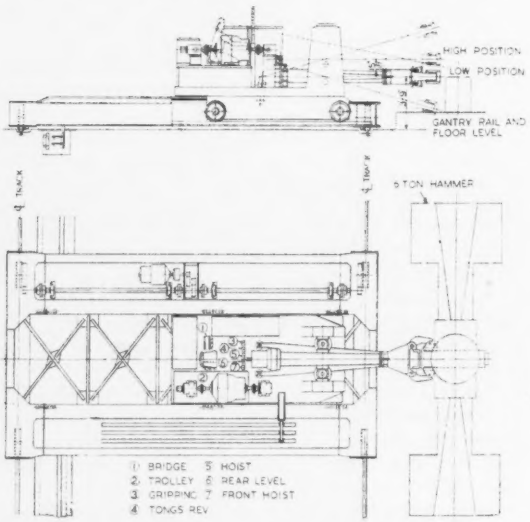


Fig. 3—Low straight-line bridge-type manipulator of 6000 lb. capacity

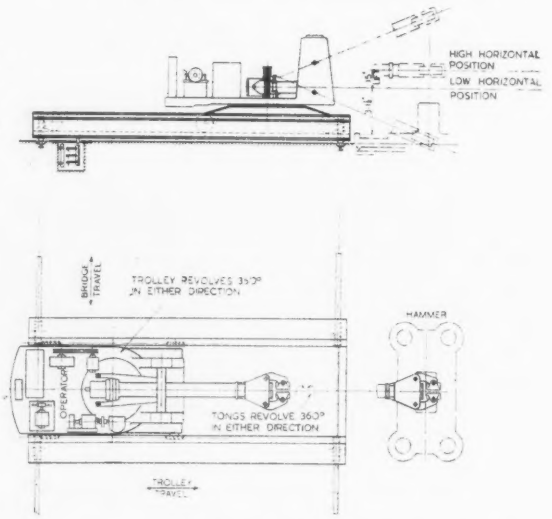


Fig. 4—Low revolving-trolley bridge-type manipulator

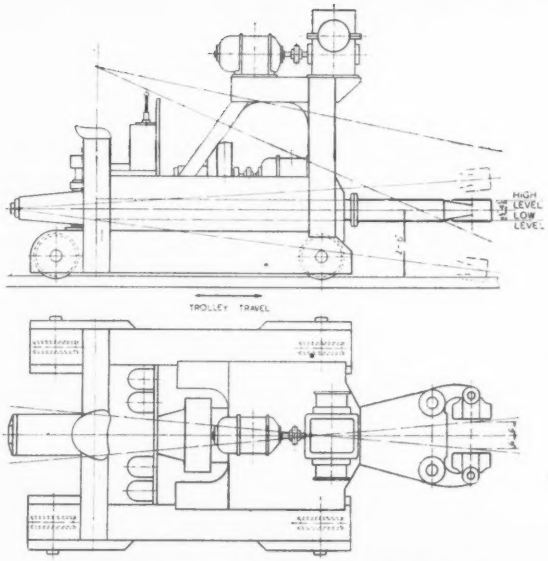


Fig. 5—High straight-line-type manipulator

a modern forging shop, the revolving-trolley bridge-type manipulator was developed. This gives any movement across the face of the press or hammer, complete revolution in either direction, and travel up and down the shop. Figure 4 is an outline sketch showing a low revolving-trolley bridge-type machine, the trolley being the same as that shown in Fig. 2.

Semi-High and High Machines

A semi-high straight-line non-revolving type of machine with a skewing device at the rear of the peel is shown diagrammatically in Fig. 5. It has the same limitations as the low straight-line type, and is usually constructed with a capacity of 6000 to 10,000 lb. Figure 6 is a line diagram of a high straight-line revolving-trolley-type manipulator which is highly rigid and robust. The upper portion revolves through a full circle in either direction. The range of the jaws is from 7 to 30 in., adaptor bits being used for the smaller ranges. This machine is used mostly for general forgings of a heavy type. Figure 7 shows a high revolving-trolley bridge-type machine of 10 tons capacity. This type of machine usually works in a pit in order to bring the work down to the height of the press.

With the semi-high type of machine and in the larger sizes, that is from 10,000 to 30,000 lb. capacity, the forgeman is interested not only in straight-line forging but also to a large extent in offset work, such as crankshafts. This offset work can be handled quite efficiently by the manipulator provided that (*a*) the unbalanced load due to offset is within the range of the turning motor, (*b*) it is not such that the motor cannot accelerate the work within a reasonable time, and (*c*) the turning moment due to offsetting is within a prescribed amount so that the special reducer casing on the turning motion is not back-driven after the motor is stopped and held by the electric brake (*see* p. 466).

The high type of machine is slower in operation

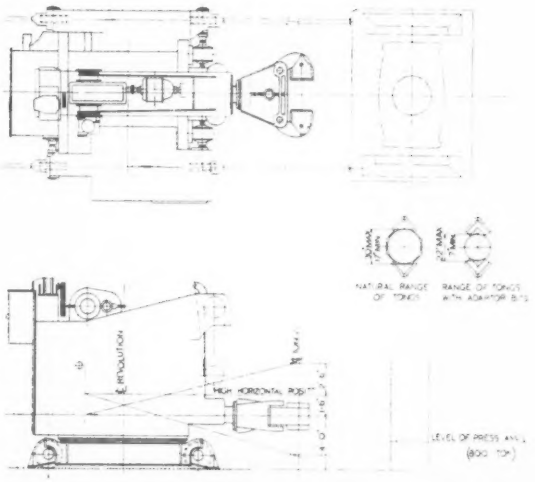


Fig. 6—Layout of 20,000-lb. manipulator for press forge

due to its increased weight and greater number of moving parts. Its greatest advantage is the rope-operated hoist which gives good shock-absorbing characteristics. It is also easier to include unlimited spring capacity to accommodate the heavy loading imposed by the compression of the forging by the hammer or press. The problem of levelling the peel in a horizontal direction when the forging is greatly reduced has been worked out for the high type of machine in a most satisfactory manner.

MOTIONS

In general, the rigid type of machine has three or more of the following seven motions :

(i) Tong gripping
(ii) Peel rotating
(iii) Hoisting
(iv) Levelling
(v) Slewing
(vi) Traverse
(vii) Bridge travelling.

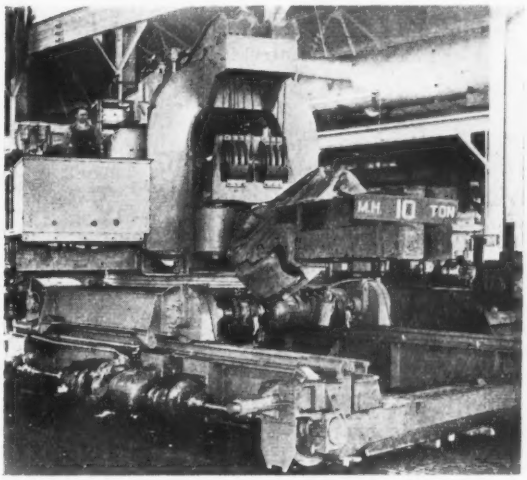


Fig. 7—High revolving-trolley bridge-type manipulator of 10 tons capacity

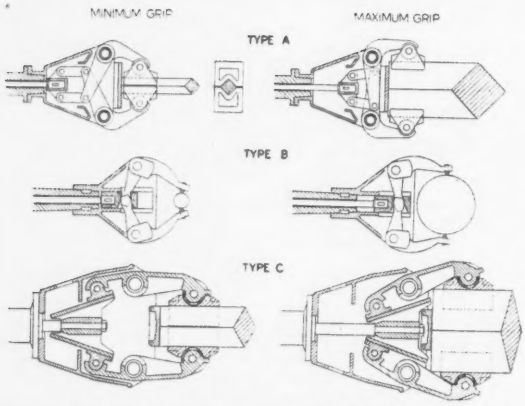


Fig. 8—Typical arrangements of tong heads. Type *A*, lever operated; type *B*, directly operated; type *C*, pneumatically operated

The last two motions follow the usual practice as applied to overhead cranes, being motor driven through reduction gears to the track wheels.

Tong Gripping

On the earlier machines, the tongs were operated by screw and nut, but a great deal of trouble was experienced owing to excessive wear on the nut, and more particularly because of the seizing of the screw in the nut ; and maintenance was difficult on account of inherent inaccessibility. Air-operated tongs were then tried, using a pneumatic system attached to the shop-line, or supplied by a self-contained compressor unit on the machine. When the conditions of handling a forging are such that the weight of the forging tends to put back-pressure on the air in the cylinders, the elasticity of air causes a considerable reduction in holding power. To overcome this, the tongs were fitted through slide blocks, at an angle such that the units were self-locking and eliminated any possibility of back-pressure in the cylinder. To secure maximum holding power, an oil hydraulic system is now being used, with a check valve fitted in the line ; the effect of back-pressure on the line is then negligible. In the latest design, the tongs can hold loads up to the capacity of the machine, with a safety factor of about two.

Figure 8 shows three typical tong-head arrangements. Type *A* shows standard lever-operated jaws, where the tong head is flange-mounted on the end of the peel arm. The gripping force is transmitted through the centre rod, moving the crosshead, which is mounted in guides, and closing the jaws on to the work. The jaws can easily be removed and replaced by a different type if necessary.

In type *B* the tong arms are operated directly from the crosshead. The tong head is attached to the peel by keys and a taper socket. Pins having wear-resisting tips are used for gripping ; this type of grip is used chiefly for the handling of wheels and die blocks. In type *C* the crosshead slides in guides, and is provided with inclined planes which engage with the slippers on the tong arms. Pressure on the ends of the tong arms is taken on large wearing surfaces. This type is used chiefly where the gripping mechanism is operated pneumatically.

Peel Rotating

Peel rotating is generally through a full circle in either direction, and is actuated either through a reversible-geared air motor or by an electric motor through planetary spur reduction. In the earlier types of machine, it was very difficult to keep the motor in position and the bearings tight, since it was found to be impossible to stop the motor at the exact instant that the press-die contacted the forging. On round forgings this condition exists almost continuously. In modern machines the drive is made through a planetary gear box, the housing being mounted in bearings which permit the entire housing to rotate. The outside of the housing is machined for contact with two adjustable brake shoes, and when the rotating motion is stopped by the hammer or press, the gear housing slips, and so eliminates the very heavy loading on the complete system of gearing and motor. Figure 9 shows two types of gripping and turning gear.

Hoisting

(i) In low-type machines hoisting is usually accomplished by means of two hydraulic cylinders, mechanically connected to ensure alignment, and operated by control valves regulating a pump which is connected to a constant-speed motor directly mounted on the oil reservoir (*see* Fig. 10).

(ii) In semi-high-type machines, a single hoisting cylinder is directly connected to four steel-wire ropes suspended from pulleys in the top of the machine ; control of the hoisting cylinder is the same as in the low type.

(iii) In high-type machines, a rope-hoisting mechanism is arranged at the front of the machine, and operated by motor, reduction gear, and hoisting drums,

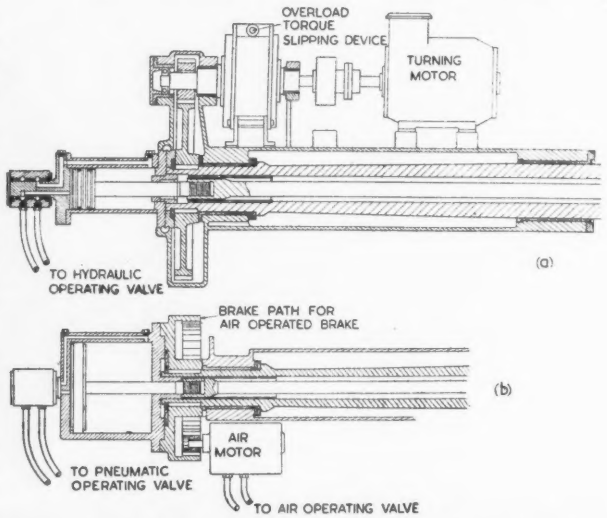


Fig. 9—Typical gripping and turning gear

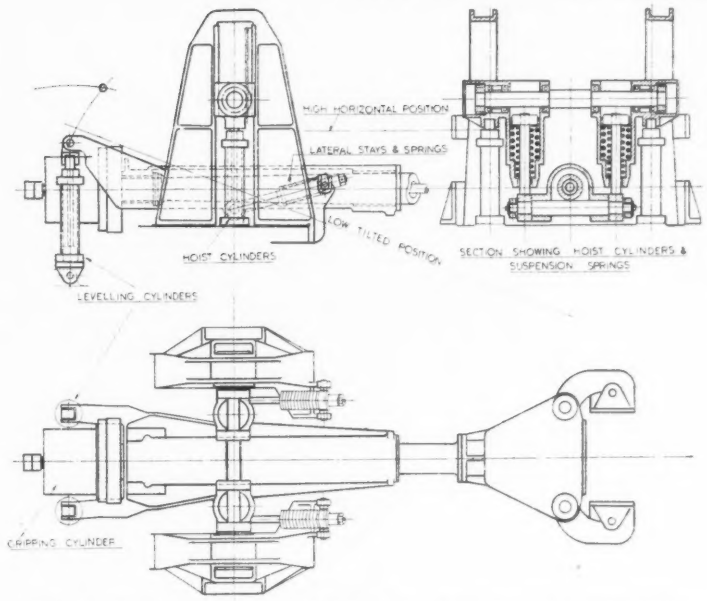


Fig. 10—Peel suspension mechanism etc., for low-type manipulator

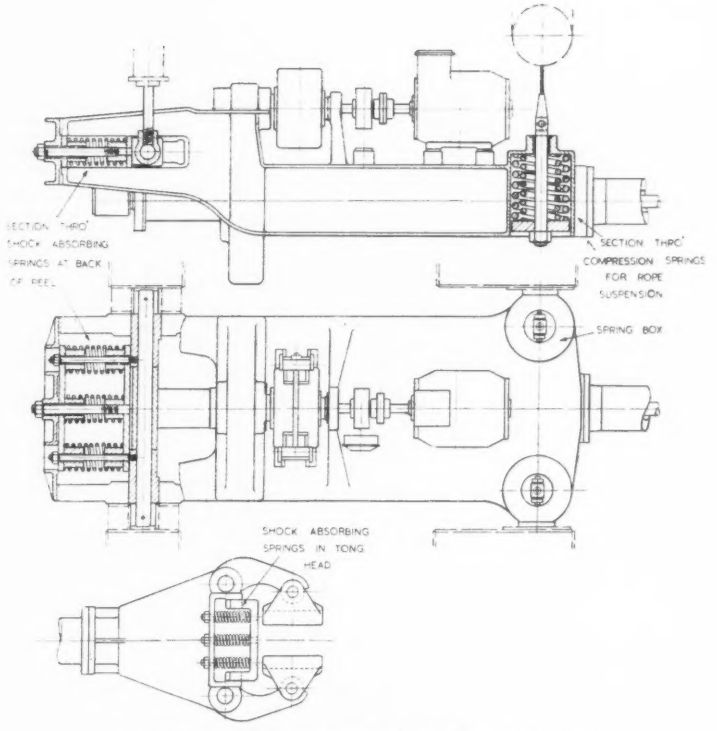

SECTION THRO' SHOCK ABSORBING SPRINGS AT BACK OF PEEL
SECTION THRO' COMPRESSION SPRINGS FOR ROPE SUSPENSION
SPRING BOX
SHOCK ABSORBING SPRINGS IN TONG HEAD

Fig. 11—Shock-absorbing springs of a manipulator

following the usual crane practice, but having, in the lower block, springs to relieve the shocks imposed when forging (*see* Fig. 11).

Levelling

The levelling mechanism is placed at the rear of the machine; in medium-sized machines it is operated by an oil hydraulic cylinder, but in the heavy types it is screw-operated, and driven by an electric motor through a worm reduction.

Slewing

This motion revolves through a full circle in either direction, and is operated by motor, worm reduction, and spur gearing. The whole of the upper portion revolves on a ball-bearing or roller path. A typical arrangement is shown in Fig. 12. The worm reduction is designed so that all driving takes place through a spring-loaded slipping-clutch coupling; if the revolving portion of the trolley meets with any external obstruction, the clutch slips and so prevents damage to the driving motor.

A TYPICAL HYDRAULIC SYSTEM

A typical layout of the hydraulic gear for a manipulator is given in Fig. 13. The peel is suspended at two points, the rear support working in vertical guides, and the front load being taken on vertical ropes connected to the peel through shock-absorbing spring boxes. The hoist cylinder is horizontally disposed, the cross-head working in guides, and the ropes passing round guide pulleys down to the peel.

The pump motor and pumps are mounted on the oil reservoir. The single pump supplies the levelling cylinder, and the dual pump supplies the hoist cylinder, and closes or opens the tongs. After the work is gripped, pressure is maintained by the small unit of the dual pump; in certain cases a hydraulic accumulator is also employed. An unloading valve is fitted so as to relieve the large capacity pump when a predetermined pressure is reached; various flow-control valves and check valves are used to ensure accurate control. When the control valves are in the neutral position the pumps are relieved of pressure, the oil being delivered back to the supply tank.

PLANT LAYOUTS

A suitable plant layout for the continuous manufacture of axles is shown in Fig. 14. The hammers

are supplied with heats by a bridge-type floor-charger. Heats are handled under the hammers by the manipulator, which forges one end of the axles, revolves the half-finished bars on an adjacent turntable, and completes the axles under the hammers. Finished axles are rolled down the gravity conveyor for disposal or reheating.

Figure 15 shows a revolving-bridge-type charger serving six furnaces arranged radially. Heats are placed on either turntable by the charger, picked up by a revolving-trolley type manipulator, forged under the hammer, and placed on the gravity conveyor for disposal. A layout that combines the forging of axles and wheels in one plant is given in Fig. 16. The charger feeds axle blanks to the turntable and wheel blanks to the fixed table.

Axles—The left-hand manipulator picks up an axle from the turntable, and forges one end under the hammer. The central manipulator then grips the forged end, completes the forging, and places the finished axle on the gravity conveyor for disposal.

Wheels—The right-hand manipulator picks up wheel blanks from the fixed table, forges blanks under the hammer, and places finished wheels on the conveyor for disposal.

Figure 17 shows a plant having a revolving-bridge-

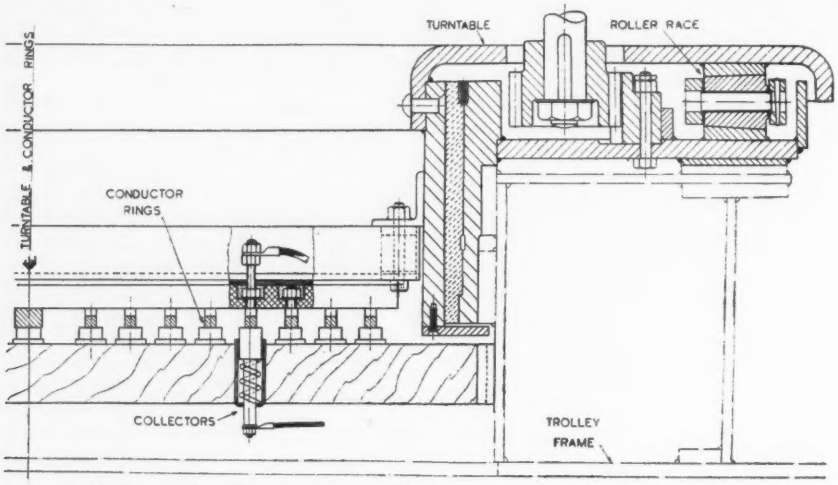
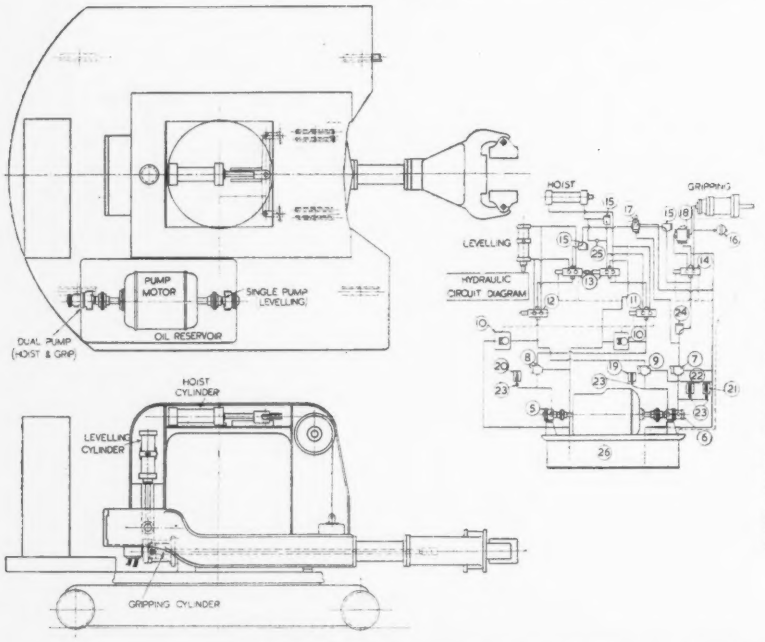


Fig. 12—Section through one half of turntable and rotary conductors



KEY

	Description	No. Off	Remarks
5	Levelling Pump	1	28 gal./min.*
6	Dual Hoist and Grip Pump	1	28 and 2 gal. min.*
7	Relief Valve	1	
8	Relief Valve	1	
9	Relief Valve	1	
10	Flow Control Valves	2	
11	Hoist Valve	1	
12	Levelling Valve	1	
13	Tandem Operating Valve	1	
14	Tong Operating Valve	1	
15	Check Valves	3	
16	Accumulator	1	850–1000 lb./sq. in.
17	Unloading Valve	1	
18	Relief Valve	1	
19	Gauge	1	200–1200
20	Gauge	1	200–1200
21	Gauge	1	200–1200
22	Gauge	1	50–350
23	¼-in. Male and Female Gauge Cocks	4	
24	¾-in. Check Valve	1	
25	¼-in. Needle Valve	1	
26	120-gal. Reservoir	1	

* American gallons.

Fig. 13—Typical layout of hydraulic gear for a manipulator

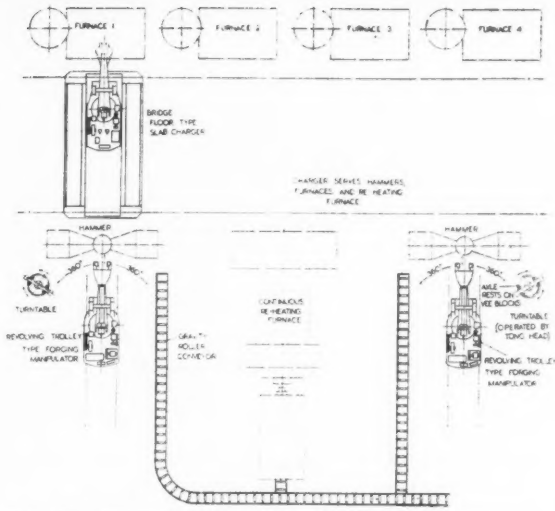


Fig. 14—Layout of forging plant for continuous manufacture of axles

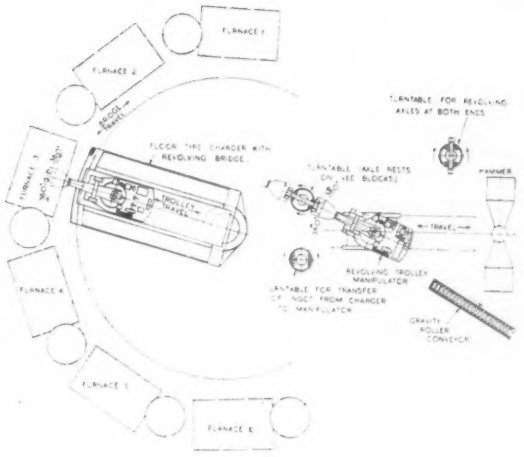


Fig. 15—A revolving-bridge-type charger serving six furnaces arranged radially

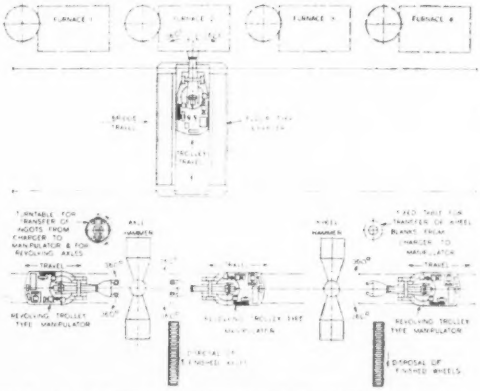

FURNACE 1
FURNACE 2
FURNACE 3
FURNACE 4
SERVICE TRAVEL
TURNTABLE FOR TRANSFER OF INGOTS FROM CHARGER TO MANIPULATOR & FOR REVOLVING AXLES
AXLE HAMMER
WHEEL HAMMER
TURNTABLE FOR TRANSFER OF WHEEL BLANKS FROM CHARGER TO MANIPULATOR
REVOLVING TROLLEY TYPE MANIPULATOR
REVOLVING ROLLER TYPE MANIPULATOR
REVOLVING TROLLEY TYPE MANIPULATOR
DISPOSAL OF FINISHED AXLES
DISPOSAL OF FINISHED WHEELS

Fig. 16—Layout of combined forging plant for axles and wheels

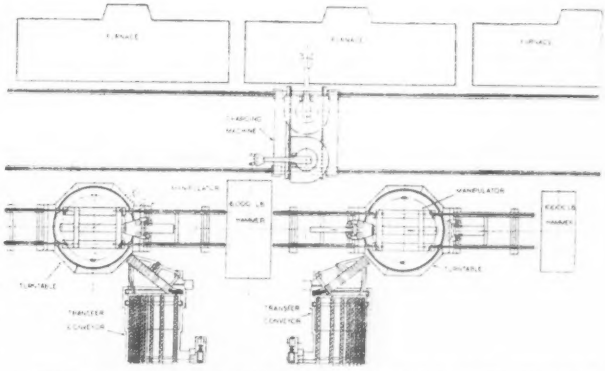


Fig. 17—Layout of forging plant operated by a charger and two straight-line-type manipulators with external turntables

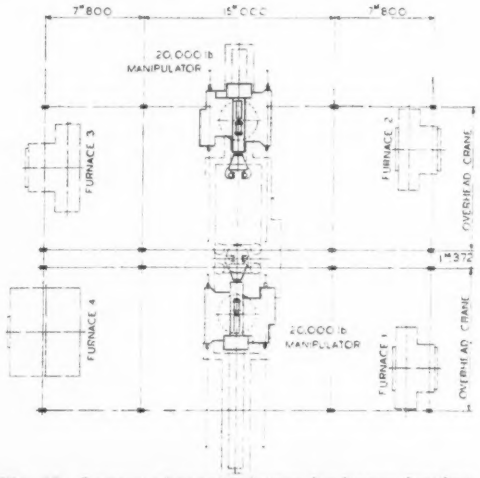


Fig. 18—Layout of manipulators for heavy forging

type charger and two straight-line-type manipulators. Ingots are transferred directly from the charger to each manipulator. Revolving is done by two railway-type turntables below the normal floor level. Completed forgings are placed on the transfer conveyors for disposal. Figure 18 shows two high straight-line-type manipulators working together in conjunction with one press. This arrangement is suitable for forging long, heavy marine shafting or gun barrels. Heats are brought to the press by overhead cranes.

OUTPUTS ATTAINED USING MANIPULATORS

(*a*) At an American plant, a 16,000-lb. hammer is served by two 4-ton straight-line-type manipulators, one on each side. In an 8-hr. shift, 103 Monel metal ingots, 14 in. square, were forged down to 8 in. × 8 in. Each ingot weighed 3100 lb.; 160 tons of these ingots were, therefore, forged in 8 hr., with a reduction of more than 3 to 1. The work was accomplished by six men, *viz.*, one man on each of the two manipulators, one hammer operator, one spell-hand, one

charging-machine operator, and one man to direct operations. Before the installation of the manipulators, two hammers and 24 men were required for the average production of 45 ingots, or approximately 70 tons, in 8 hr. The tonnage production per man is now more than nine times greater than it was.

(*b*) On an installation producing high-silicon steel for electric sheets, two manipulators in conjunction with a 1000-ton steam-hydraulic press give an average 8-hr. production of 120 ingots whose size is reduced from 15 in. × 15 in. × 49 in. to 6½ in. square. These ingots weigh a little over 3000 lb. each, making the production approximately 200 tons in 8 hr. During the recent war, on this particular plant, a normal production of 120 ingots per 8-hr. shift was maintained when forging chromium–molybdenum steel.

(*c*) At another plant, using two 6000-lb. manipulators working each side of a 1000-ton steam-hydraulic press and dealing with billets of high-silicon steel, each billet, 13½ in. square and weighing 2650 lb., was taken from the furnace, forged to 6 in. × 5½ in., and passed to the conveyor in 3 min. operating time.

APPENDIX

Typical Design Calculations for a 10-ton 'High'-Type Manipulator

LOAD CALCULATIONS

Size of Pieces Handled

To find the length l and diameter d for a bar which is equivalent to nominal load :

(1) For equal load on hoisting ropes at B

Weight of steel bar of dia. d and length $l = 0{\cdot}7854 \times d^2 \times l \times 0{\cdot}284$ lb. $= 0{\cdot}223d^2l$ lb.

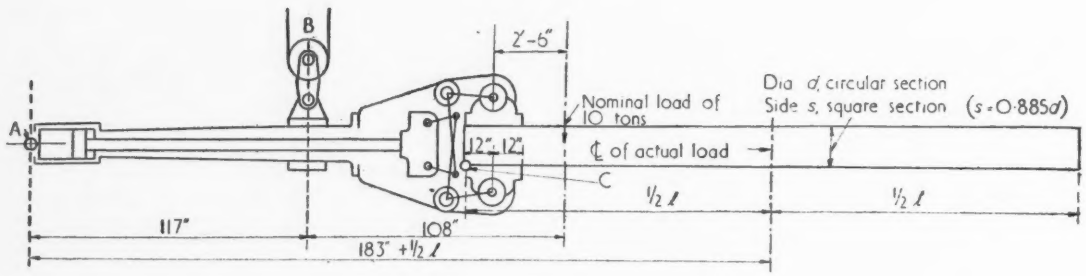
Moment of nominal load about fulcrum $A = 10 \times 2240$ lb. $\times 225$ in. $= 5{\cdot}05 \times 10^6$ in.lb.

Moment of actual load about fulcrum $A = W\,(183 + \frac{1}{2}l) = 0{\cdot}223d^2l\,(183 + \frac{1}{2}l) = 40{\cdot}8d^2l + 0{\cdot}112d^2l^2$
$= (0{\cdot}112d^2)l^2 + (40{\cdot}8d^2)l$

Equating actual and nominal load moments

$$(0{\cdot}112d^2)l^2 + (40{\cdot}8d^2)l = 5{\cdot}05 \times 10^6$$
$$(0{\cdot}112d^2)l^2 + (40{\cdot}8d^2)l - 5{\cdot}05 \times 10^6 = 0$$

$$l = \frac{-40{\cdot}8d + \sqrt{1660d^2 + 2{\cdot}26 \times 10^6}}{0{\cdot}224d}$$



(2) For equal load at centre of jaw

Moment of nominal load about point $C = 10 \times 2240 \times 42$ in.lb. $= 0{\cdot}94 \times 10^6$ in.lb.

Moment of actual load about point $C = W \times \frac{1}{2}l = 0{\cdot}223d^2l \times \frac{1}{2}l = 0{\cdot}112d^2l^2$

Equating actual and nominal load moments : $(0{\cdot}112d^2l^2 = 0{\cdot}94 \times 10^6$; $l = \sqrt{\dfrac{0{\cdot}94 \times 10^6}{0{\cdot}122d^2}} = \dfrac{2900}{d}$

d, in.	l, Calculated from (1), in.	l, Calculated from (2), in.	Minimum Weight, lb.
12	405	242	7180
14	330	208	9100
16	280	181	10,350
18	233	161	11,620
20	200	145	12,920
22	173	132	14,220
24	151	121	15,580
26	134	112	16,900
28	120	104	18,150
30	106	97	19,500
32	95	91	20,800
34	87	85	21,900

The gripping cylinder is 12 in. dia. × 13 in. stroke, with 4 in. dia. rod. Net area = 100·53 sq. in.
Maximum pull on rod with 1000 lb./sq. in. oil pressure = 100,530 lb.

Total movement at jaw = 16 in. Equivalent load at jaw $= \frac{13}{16} \times 100{,}530$ lb. = 81,900 lb.

Moment about point C (jaws locked) = $81{,}900 \times 24 = 1{\cdot}986 \times 10^6$

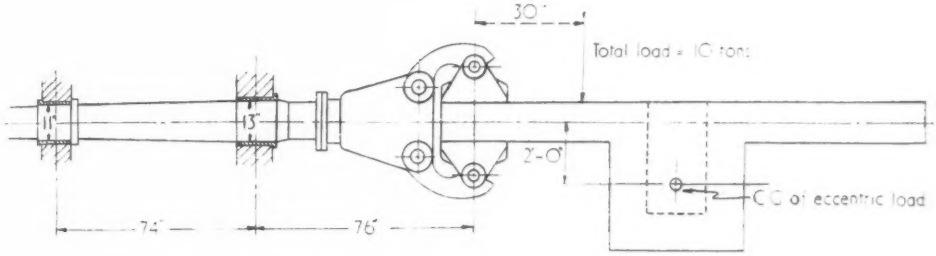
PEEL REVOLVING CALCULATIONS

Pressure on 13-in. bearing $= \frac{180}{74} \times 10 \times 2240 = 54{,}500$ lb. Friction moment = $54{,}500 \times 0{\cdot}15 \times 6\frac{1}{2}$ = 53,000 in.lb.

Pressure on 11-in. bearing $= \frac{106}{74} \times 10 \times 2240 = 32{,}100$ lb. Friction moment = $32{,}100 \times 0{\cdot}15 \times 5\frac{1}{2}$ = 26,500 in.lb.

Total friction moment = 79,500 in.lb. = 6625 ft.lb.

Motor torque (2 × full load) $= \frac{40 \times 5250}{750} = 280$ ft.lb. Equivalent torque at peel $= 280 \times 12 \times \frac{91}{14}$ = 21,800 ft.lb.



Taking transmission efficiency of 0·8, actual torque at peel = $0{\cdot}8 \times 21{,}800 = 17{,}440$ ft.lb.
∴ Torque available at peel for turning and accelerating load = $17{,}440 - 6625 = 10{,}815$ ft.lb.

$I = \frac{W}{g}k^2$ for motor armature = 0·85 (assumed). $I = \frac{W}{g}k^2$ for brake drum and gears = 0·2 (assumed).

Total I at motor shaft = 1·05

Equivalent I at peel $= \left(\frac{750}{9{\cdot}62}\right)^2 \times 1{\cdot}05 = 6080 \times 1{\cdot}05 = 6400$. 9·62 r.p.m. = 1 radian/sec.

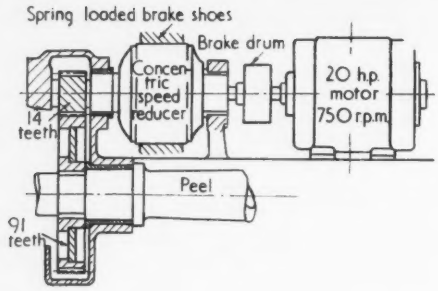
Peel and tongs (say) 35,000 lb. at 6 in. radius. $I = \frac{35{,}000}{32{\cdot}2} \times (\frac{1}{2})^2 = 272$. Total $I = 6672$.

Off-Centre Load w, cwt.	Torque due to w,* ft.lb.	Torque from Motor	Available Torque for Acceleration, ft.lb. (T)	$I = \frac{W}{g}k^2$ Motor, etc.	Load†	Total	Angular Acceleration $= \frac{T}{I} = \alpha$	Time to Accelerate to 1 radian/sec.,‡ sec.	Time for 90° Movement, sec.
5	778	10,815	10,037	6672	35	6707	1·49	0·67	1·89
10	1568	10,815	9247	6672	69	6741	1·37	0·73	1·93
15	2352	10,815	8463	6672	104	6776	1·25	0·8	1·97
20	3136	10,815	7679	6672	139	6811	1·13	0·885	2·01
25	3920	10,815	6895	6672	174	6846	1·005	1·0	2·07
30	4704	10,815	6111	6672	208	6880	0·89	1·125	2·13
35	5488	10,815	5327	6672	243	6915	0·772	1·3	2·22
40	6272	10,815	4543	6672	278	6950	0·65	1·54	2·33

* Torque due to w taken as 0·7 × max. torque (sin 45° ≅ 0·7).
† I for off-centre load = 0·5 × full value.
‡ Angular movement θ radians = $\frac{1}{2}\alpha t^2$; $t = \sqrt{\frac{2\theta}{\alpha}}$

Horse-power required to turn peel and load after acceleration to full speed (9·62 r.p.m.)
$= \frac{6625 \times 9{\cdot}62}{5250 \times 0{\cdot}8} = 15{\cdot}2$

Spring on brake shoes : 2500 lb./in. Compression. $\frac{1}{2}$-in. compression = 1250 lb.



Holding torque on $23\frac{1}{4}$-in. dia. load =

$$2 \times 1250 \times 2 \times 0{\cdot}4 \times \frac{11\frac{5}{8}}{12} = 1940 \text{ ft.lb.}$$

Equivalent torque at peel = $1940 \times \frac{91}{14}$

$= 12{,}600$ ft.lb.

Torque at peel, from motor (2 × full load)

$= 10{,}815$ ft.lb.

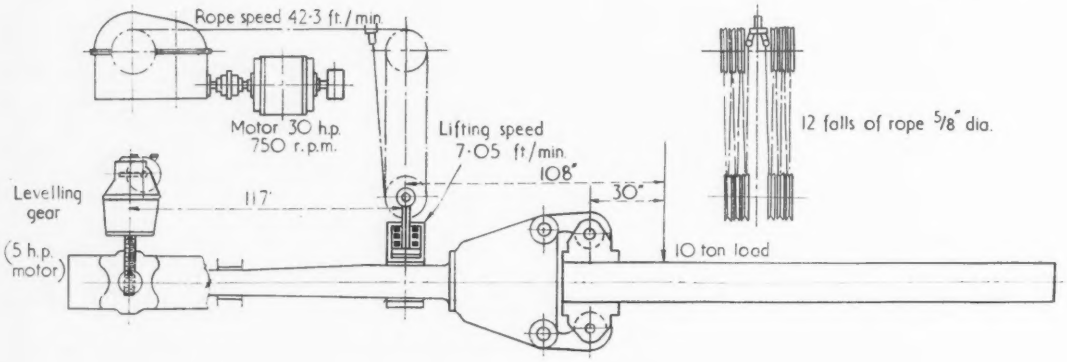
This can be transmitted without slipping.

HOIST GEAR CALCULATIONS

Load on ropes = $\frac{225}{17} \times 10 \times 2240 - 35{,}000$ (peel and tongs) $= 43.000 + 35{,}000 = 78{,}000$ lb. on 12 falls of rope

Load per rope = $\frac{78{,}000}{12} = 6500$ lb. Rope $\frac{5}{8}$ in. dia. has a breaking load = 14·4 tons = 32,300 lb.

Safety factor = 5



Hoist motor 30 h.p., 750 r.p.m. Hoist speed at block = 7·05 ft./min. = 11·75 ft./min. at jaws.

Theoretical h.p. required to raise 78,000 lb. at 7·05 ft. min. = $\frac{78{,}000 \times 7{\cdot}05}{33{,}000} = 16{\cdot}7$

Assuming an overall efficiency of 70%: Motor h.p. required = $\frac{16{\cdot}7}{0{\cdot}7} = 23{\cdot}8$.

Spring Suspension of Peel

Compression rate for springs (2 large and 16 small) = 30,000 lb./in. total.

Compression from free length when under load = $\frac{78{,}000}{30{,}000} = 2{\cdot}6$ in.

Maximum compression of springs = $4\frac{3}{4}$ in.

Load = 142,500 lb. = 1·83 × normal max. load.

with an available further deflection of $4{\cdot}75 - 2{\cdot}6 = 2{\cdot}15$ in.

TRAVERSE CALCULATIONS

Complete weight of machine with 10-ton load = 142,400 lb.

Motor with driving shaft at each end coupled to a concentric speed reducer, is actually used on 10-ton manipulator, which also has duplicate drive for the other 2 runners.

All calculations are based on single drive shown.

$$\text{Traverse speed} = 750 \times \frac{1}{50} \times 2 \times \pi = 94{\cdot}2 \text{ ft./min.} = 1{\cdot}57 \text{ ft./sec.}$$

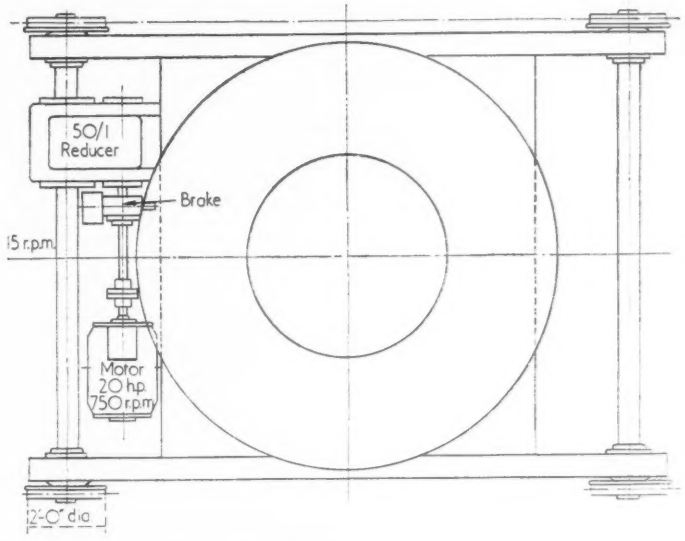
Taking a coefficient of 0·002 for rolling friction and 0·005 for roller bearing friction, then

Tractive effort to move machine $= \frac{0{\cdot}002}{12} \times 142{,}400 + 0{\cdot}005 \times 142{,}300 \times \frac{4\frac{1}{4}}{24}$

$= 237 + 126 = 363$ lb.

Theoretical h.p. to move machine against friction at 94·2 ft. min. $= \frac{363 \times 94{\cdot}2}{33{,}000} = 1{\cdot}035$ h.p.

Assuming 2 × (full load) torque available at motor during acceleration $= \frac{40 \times 5250}{750} = 280$ ft.lb.



Equivalent torque at runner axle = 50 × 280 = 14,000 ft.lb.
Taking transmission efficiency as 0·85, actual torque at runner = 11,900 ft.lb. = 11,900 lb. at 1 ft. radius.
Force available for acceleration = 11,900 − 363 = 11,537 ft.lb. at 1 ft. radius. ∴ $T = 11{,}537$.

Assuming $I = \frac{W}{g}k^2 = 1{\cdot}0$ at motor shaft for motor armature and gears etc. :

Equivalent I for motor at 15 r.p.m. $= \left(\frac{750}{15}\right)^2 \times 1 = 2500$. Equivalent I for load at 1 ft. radius $= \frac{142{,}400 \times 1^2}{32{\cdot}2} = 4440$

Total $I = 6940$

Angular acceleration of runner $= \frac{T}{I} = \frac{11{,}537}{6940} = 1{\cdot}67$ radians sec./sec.

Linear acceleration of runner = 1·67 × 1 = 1·67 ft./sec. sec.

Time required to accelerate to full speed $= \frac{1{\cdot}57}{1{\cdot}67} = 0{\cdot}94$ sec.

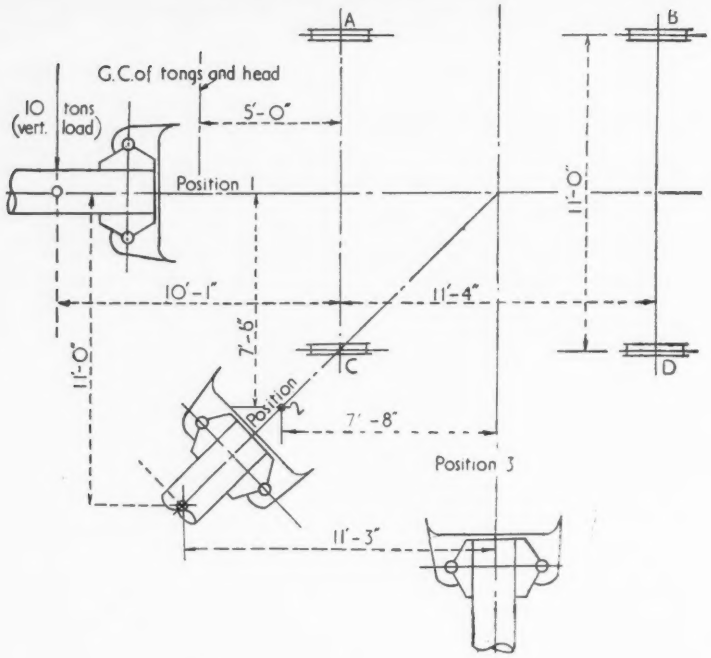
Distance travelled, $s = \frac{1}{2}at^2 = \frac{1}{2} \times 1{\cdot}67 \times 0{\cdot}94^2 = 0{\cdot}735$ ft.

WHEEL LOAD AND STABILITY CALCULATIONS

Weight of complete machine = 120,000 lb. Weight of tongs and head = 12,000 lb.
Position 1. Taking moments about *BD* :

	Load		Tongs and Head	Complete machine less tongs and head
Resultant load on *AC*	$22{,}400 \times \frac{21 \text{ ft. } 5 \text{ in.}}{11 \text{ ft. } 4 \text{ in.}}$	−	$12{,}000 \times \frac{16 \text{ ft. } 4 \text{ in.}}{11 \text{ ft. } 4 \text{ in.}}$	$- \frac{108{,}000}{2}$
	42,500	+	17,300	− 54,000

Total = 113,800 lb. ∴ Load on runners *A* and *C* = 56,900 lb.



Position 3. Taking moments about AB:

Load		Tongs and Head		Complete machine less tongs and head
$22{,}400 \times \frac{21 \text{ ft. } 3 \text{ in.}}{11 \text{ ft. } 0 \text{ in.}}$	+	$12{,}000 \times \frac{16 \text{ ft. } 2 \text{ in.}}{11 \text{ ft. } 0 \text{ in.}}$	+	$\frac{108{,}000}{2}$
43,300	+	176,000	+	54,000

Total = 114,900 lb. $\therefore$ Load on runners C and D = 57,450 lb. each.

Position 2. Taking moments about BD and AB:

Load		Tongs and Head		Complete machine less tongs and head
$\left(22{,}400 \times \frac{16 \text{ ft. } 11 \text{ in.}}{11 \text{ ft. } 4 \text{ in.}} \times \frac{16 \text{ ft. } 6 \text{ in.}}{11 \text{ ft. } 0 \text{ in.}}\right)$	+	$\left(12{,}000 \times \frac{13 \text{ ft. } 4 \text{ in.}}{11 \text{ ft. } 4 \text{ in.}} \times \frac{13 \text{ ft. } 0 \text{ in.}}{11 \text{ ft. } 0 \text{ in.}}\right)$	+	$\frac{108{,}000}{4}$
50,100	+	16,700	+	27,000

Total = 93,800 lb. = Load on runner C

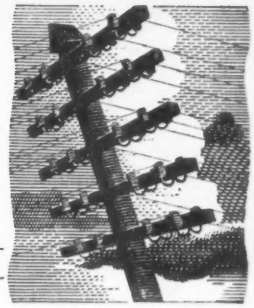
For positions 1 and 3 the max. wheel load on runners nearest to tongs is 114,900 lb.

Then load on remaining runners = 142,400 − 114,900 = 27,500 lb. : therefore machine is stable.

For position 2, the runner directly under the peel is loaded to 93,800 lb. Then load on remaining 3 runners = 142,400 − 93,800 = 48,600 lb.

If this remaining load was carried on 2 runners only, *i.e.*, A and D, the machine would be stable.

N E W S



ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1950

The Annual General Meeting of The Iron and Steel Institute will be held at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, 26th and 27th April, 1950.

The following is a detailed programme :

Wednesday, 26th April, 1950

Morning Session

10.0 A.M. to 11.0 A.M.
- Official business and election of Members
- Presentation of Report of Council and Statement of Accounts for 1949
- Presentation of the Bessemer Gold Medal, and the Sir Robert Hadfield Medal, for 1950
- Presentation of the Andrew Carnegie Silver Medal for 1949
- Presentation of the Williams Prize, and the Ablett Prize, for 1949
- Induction of the President-Elect, Mr. J. R. MENZIES-WILSON, O.B.E.

11.0 A.M. to 11.45 A.M.—Presidential Address

11.45 A.M. to 12 NOON—Interval

12 NOON to 1.15 P.M.—Discussion on :
- "*Characteristics of Scrap in Relation to Bulk Handling*," by E. L. Diamond (*April*, 1950).

1.15 P.M. to 2.30 P.M.—Buffet Luncheon

Afternoon Session

2.30 P.M. to 4.0 P.M.—Joint Discussion on :
- "*The Overheating and Burning of Steel : Part III—The Influence of Excessive Reheating Temperatures on the Mechanical Properties and the Structure of Alloy Steels*," by A. Preece, J. Nutting, and A. Hartley (*January*, 1950)
- "*The Detection of Overheating and Burning in Steel by Microscopical Methods*," by A. Preece and J. Nutting (*January*, 1950)
- "*Grain-Boundary Phenomena in Severely Heated Steel*," by T. Ko and D. Hanson (*January*, 1950)
- "*A Note on the Overheating of Steel*," by E. C. Rollason and D. F. T. Roberts (*April*, 1950)

4.0 P.M. to 5.0 P.M.—Discussion on :
- "*The Extension of the Ar_1 Range with Carbide Formation in Mild Steel due to High-Temperature Treatment*," by J. H. Whiteley (*April*, 1950)

Evening

8.30 P.M.—"*Sidney Gilchrist Thomas*"—Commemorative Lecture by James Mitchell, C.B.E. (Honorary Treasurer)

Thursday, 27th April

Morning Session

10.0 A.M. to 11.0 A.M.—Discussion on :
- "*The Influence of Low Percentages of Certain Elements on the Microstructure of Pure Iron-Carbon Alloys and Cast Irons*," by W. J. Williams (*April*, 1950)

11.0 A.M. to 11.30 A.M.—Interval

11.30 A.M. to 1.0 P.M.—Joint Discussion on :
- "*The Thermodynamic Background of Iron and Steel Making Processes : I—The Blast-Furnace*," by F. D. Richardson and J. H. E. Jeffes (*December*, 1949)
- "*The Influence of Gas/Solid Temperature Differences on Blast-Furnace Operation*," by J. Taylor (*February*, 1950)

1.0 P.M. to 2.30 P.M.—Buffet Luncheon

Afternoon Session

2.30 P.M. to 3.45 P.M.—Joint Discussion on :
- "*Blast-Furnace Gas Cleaning : An Analysis of Plant Performance*," by R. F. Jennings (*March*, 1950)
- "*Blast-Furnace Gas Cleaning : Methods for Calculating the Motions of Particles in a Gas*," by J. Stringer (*March*, 1950)

3.45 P.M. to 5.0 P.M.—Joint Discussion on:
- "*Proposals for the Modification of a Blast-Furnace Top to give Controlled Burden Distribution*," by E. L. Diamond (*February*, 1950)
- "*A New Blast-Furnace Stock-Rod Gas Seal*," by E. J. Walklate (*December*, 1949)

Evening

7.0 for 7.30 P.M.—Members' Dinner at the Dorchester Hotel, Park Lane, London, W.1.—Members and their Guests should use the Ballroom Entrance.

NOTE—The issues of the *Journal* in which the papers appear are given in brackets.

Awards

Bessemer Gold Medal

The Bessemer Gold Medal for 1950 has been awarded to Mr. **James Mitchell, C.B.E.,** Director of Messrs. Stewarts and Lloyds, Ltd., and Honorary Treasurer to the Institute.

Sir Robert Hadfield Medal

The Sir Robert Hadfield Medal for 1950 has been awarded to Mr. **G. D. Elliott,** Blast-Furnace Superintendent at the Scunthorpe Works of the Appleby-Frodingham Steel Co., Ltd.

Andrew Carnegie Medal

The Andrew Carnegie Silver Medal for 1949 has been awarded to Mr. **N. H. Polakowski, Dipl.Ing.,** for his report on "*The Compression Test in Relation to Cold Rolling*."

Williams Prize

The Williams Prize for 1949 has been awarded jointly to Dr. **D. F. Marshall,** Fuel and Refractories Officer, and to Mr. **H. C. White,** Development Engineer, both of The Park Gate Iron and Steel Co., Ltd., Rotherham, for their paper on "*The Conversion to Oil Firing of the Open-Hearth Furnaces at Park Gate Works.*"

Ablett Prize

The Ablett Prize for 1949 has been awarded jointly to Mr. **E. L. Diamond,** formerly Head of the Mechanical Section, Plant Engineering Division, B.I.S.R.A., and now Assistant Technical Director of the British Standards Institution, and to Mr. **A. M. Frankau,** Assistant Mechanical Engineer in the Plant Engineering Division of B.I.S.R.A., for their paper on "*Present Methods of Open-Hearth Furnace Charging.*"

Symposium on High-Temperature Steels and Alloys for Gas Turbines

The Symposium will be held in London on **Wednesday** and **Thursday, 18th** and **19th October, 1950,** and not on Thursday and Friday, 19th and 20th October, as announced in the March issue of the *Journal.*

Air Commodore Sir Frank Whittle, K.B.E., C.B., D.Sc., F.R.S., will deliver the Fifth Hatfield Memorial Lecture on the **Tuesday** evening (**17th**) prior to the Symposium. (Tentative date.)

Rolling Mill Bibliography

A bibliography on The Rolling of Iron and Steel, No. 15 in the Institute's series, has been prepared by the Library and Information Department. The bibliography covers, very extensively, the period between 1920 and 1947, but selected references to literature published before 1920 are included. It also includes references to the manufacture of seamless tubes.

Bound, duplicated stencilled copies, in two volumes totalling 457 foolscap pages, may be obtained on application to the Secretary at 4 Grosvenor Gardens, London, S.W.1, price 25*s.* (15*s.* to Members).

NEWS OF MEMBERS

▶ Mr. B. ARNOLD is now a metallurgical student at the Central Technical College, Suffolk Street, Birmingham.

▶ Mr. G. BARBER has joined the staff of Messrs. William Jessop and Sons, Ltd., Sheffield.

▶ Mr. AUSTIN BEVAN has transferred from Cardiff to the Dowlais Works of Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd.

▶ Mr. S. N. CHATTERJEE is now working in the Works Metallurgical Department of Messrs. Stewarts and Lloyds, Ltd., Corby.

▶ Mr. C. R. DUNN, late European Representative of Messrs. British Timken, Ltd., has been appointed Sales Manager of the Fischer Bearings Co., Ltd., Wolverhampton.

▶ Mr. J. C. HANNAM has left the British Iron and Steel Research Association to take up a post in the Metallurgy Department of the Royal Aircraft Establishment, Farnborough, Hants. He will work on the development of magnesium–lithium alloys.

▶ Mr. J. B. HAWORTH has left the Inorganic Chemistry Laboratory, University of Oxford, to take up a position as Research Metallurgist with Murex Ltd., Rainham.

▶ Dr. BRYNMOR JONES and Mr. G. I. RUSHTON, Special Directors of the Whitehead Iron and Steel Co., Ltd., Newport, Mon., have been elected to the Board of Directors.

▶ Mr. R. M. V. PERRIN has been nominated Officier de la Légion d'Honneur.

▶ Mr. G. P. TINKER has been appointed Managing Director of Messrs. Birlec Limited, Birmingham, in succession to the late Mr. A. G. Lobley. Mr. Tinker has been a member of the executive staff of the Company since its formation in 1927.

▶ Mr. G. A. TURNBULL has joined the Department of Research and Technical Development of Messrs. Stewarts and Lloyds, Ltd., Coatbridge, as a Metallurgist.

▶ Mr. H. A. A. WHILE has been appointed London Manager of The United Steel Companies Ltd. He will remain in charge of the Railways Department.

▶ Mr. J. R. WILLIAMS has taken up an appointment as Metallurgist in the Research Department of Needle Industries, Ltd., Studley, Warwick.

Obituary

Monsieur EMILE HOUBAER, Directeur de la Société Anonyme John Cockerill, on 19th February, 1950.

Mr. J. W. SUMMERS, Chief Engineer at the Normanby Ironworks of Messrs. Pease and Partners, Ltd., on 14th November, 1949.

Mr. HENRIK RUDOLF SUNSTROM, President of Gunnebo Bruks Aktiebolag, Sweden, on 21st November, 1949.

Mr. G. H. HARRISON of Swansea, in April, 1949.

Mr. W. G. HUTTON, Assistant Melting-Shop Manager at the Clydebridge Steelworks of Messrs. Colvilles Ltd., on 25th February, 1950.

CONTRIBUTORS TO THE JOURNAL

G. E. Eden, B.Sc., A.R.I.C.—Scientific Officer at the Water Pollution Research Laboratory, Watford. Mr. Eden was born in 1922 and was educated at the Harrow County School. In 1945 he obtained the degree of B.Sc. of London University with first-class honours in Special Chemistry.

He joined the staff of the Water Pollution Research Laboratory in 1940 and is now engaged in research on the chemical aspects of the treatment of industrial waste waters.

G. A. Truesdale—A member of the staff of the Water Pollution Research Laboratory, Watford. Mr. Truesdale was born in 1927 at Erdington, Birmingham. He was educated at King Edward's High School, Birmingham, and at Bishop Vesey's Grammar School, Sutton Coldfield.

After a period of employment with the Dunlop Rubber Company, Ltd., he joined the staff of the Water Pollution Research Laboratory in 1947, and is now engaged in work on the dynamics of water aeration.

G. E. Eden

G. A. Truesdale

D. A. Wise

H. A. Chapman

W. J. Williams

L. N. Bramley

G. C. Ellis, M.Sc., A.I.M.—Senior Scientific Officer at the Armament Research Department, Ministry of Supply. Mr. Ellis graduated in metallurgy, in 1940, at the University College, Swansea. After service with the Mond Nickel Company as a research chemist, he joined the Metallurgical Branch of the Armament Research Establishment, Ministry of Supply, in 1941. Although he has since remained with the A.R.D. as a Senior Scientific Officer, Mr. Ellis has travelled in Europe and the U.S.A. For a short period in 1945 and for 18 months commencing in 1946 he served as Metallurgical Representative of B.I.O.S., Ministry of Supply, in both Austria and Germany. Since early 1949 he has acted, on a temporary basis, as Metallurgical Liaison Officer with the United Kingdom Scientific Mission, Washington, U.S.A., under the auspices of the D.S.I.R. Overseas Liaison Division (North America).

The foregoing three contributors were joint authors of papers published in the March issue of the Journal. The biographical notes were not available in time for inclusion in that issue.

D. A. Wise, B.Sc.—Assistant electrical engineer in the Plant Engineering Division of the British Iron and Steel Research Association. He was born at Knowle, in Warwickshire, in 1924, and received his general education at the City of Oxford High School and at Solihull School. He later went to the University of Birmingham for further technical training and there graduated in electrical engineering in 1944.

Mr. Wise served for two years as an electrical officer in the Royal Naval Volunteer Reserve before taking up his present appointment in June 1947. He was elected a Member of The Iron and Steel Institute in 1947.

H. A. Chapman, B.Sc.—Assistant electrical engineer in the Plant Engineering Division of The British Iron and Steel Research Association. He was born at Keighley in 1924, and was educated at Giggleswick School and at Leeds University, where he obtained an honours degree in electrical engineering in 1943. He then served for three years in the Royal Navy as an electrical officer.

In January 1947 Mr. Chapman joined the Research and Development Department of Tube Investments (Group Services) Ltd., Birmingham, where he worked on the application of induction heating methods to the heat-treatment of stainless steel tubes. He joined the staff of the Association in 1948.

Mr. Chapman was elected a Member of The Iron and Steel Institute in 1948.

W. J. Williams, M.Sc.—Metallurgist on the Research Staff of the British Cast Iron Research Association. He was born at Ystradgynlais in 1921, and was educated at the local Secondary School, matriculating in 1937. He obtained a Central Welsh Board Higher School Certificate and entered Swansea University College in 1939, and in 1942 he obtained the degree of B.Sc. in metallurgy. He gained the M.Sc. degree of the University of Wales in 1948. During vacation courses he received practical experience at local steelworks and rolling mills and also at copper smelting and refining works in Swansea.

In 1942, Mr. Williams joined Messrs. Morris Motors, Ltd., Coventry, and was engaged in the Foundry Department on the production and casting of electric-furnace-melted manganese steel, and in research work on core oil substitutes. He joined the staff of the Association as metallurgist, in 1943, and has since worked on researches into graphite formation during solidification of cast iron and other factors in relation to the production and properties of cast iron.

In 1948 an award from the Andrew Carnegie Trust Fund was made to Mr. Williams, and his paper, published in this issue of the *Journal*, describes the results of the work carried out with the aid of this grant.

Elected a Member of The Iron and Steel Institute in 1947, Mr. Williams is also an Associate Member of the Institute of British Foundrymen, and an Associate of The Institution of Metallurgists.

Dr. **L. N. Bramley, Ph.D.(Eng.), A.M.I.E.E.**—Head of the Electrical Section of the British Iron and Steel Research Association. Dr. Bramley was born in 1908 and was educated at the Roan School, London, and at the Brighton, Hove and Sussex Grammar School. After a preliminary training period of three years with Messrs. Johnson and Phillips, Ltd., London, he left in 1927 to attend courses at the City and Guilds College, London. He obtained the B.Sc.(Eng.) degree with first-class honours in heavy electrical engineering, in 1929, and also obtained the Associateship of the City and Guilds Institute.

After carrying out post-graduate work on advanced electrical machinery at the College for a year he was awarded the Diploma of the Imperial College, and he obtained the M.Sc.(Eng.) degree as a result of his studies of surge recording by means of the klydonograph.

Dr. Bramley left the College in 1930 to join the staff of the Henley Research Laboratories, where he investigated dielectric phenomena related to high-voltage cables, and advanced the technique of loss measurement by means of the Schering Bridge. As a result of this work he was awarded the degree of Ph.D.(Eng.) in 1947. He then joined the Electrical Department of the Royal Aircraft Establishment and was later transferred to take charge of the Instrument Section of the Materials Division.

In 1945 Dr. Bramley took up his present position with the British Iron and Steel Research Association. He became a Member of The Iron and Steel Institute in 1946.

IRON AND STEEL ENGINEERS GROUP

The THIRTEENTH MEETING of The Iron and Steel Engineers Group will be held at 4 Grosvenor Gardens, London, S.W.1, on Wednesday, 28th June, 1950.

Details of the programme will be announced in later issues of the *Journal*.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Painting of Structural Steelwork

A second interim report on the painting of structural steelwork has been published by the British Iron and Steel Research Association. The performance of paints for this purpose is being exhaustively investigated by a Joint Technical Panel of the Association's Protective Coatings Sub-Committee. Eleven hundred and seventy-eight specimens have been exposed in an industrial or marine atmosphere, at Derby and Brixham respectively, to test two hundred and sixty-one different paint formulations.

The earliest exposures, to test priming paints, began in October 1945, and a first interim report was published in December 1946. In March 1947 further exposures, to test metallic pigments and lead soaps, were begun, and a year later two further series, respectively to test surface preparations and metallic coatings, and bituminous and tar paints.

This second interim report draws some tentative conclusions from the first two series.

The interim report and reprints are available free of charge from the British Iron and Steel Research Association, 11 Park Lane, London, W.1.

Reprints are also available from the B.I.S.R.A. Corrosion Laboratory, 514 Bristol Road, Selly Oak, Birmingham, 29.

INSTITUTE OF METALS

Students Educational Tour

An educational tour of representative metallurgical and engineering works and laboratories in the Sheffield area has been arranged for student members of the Institute, to take place from Monday to Friday, 17th–21st April, 1950. The tour covers many works making iron and steel or manufacturing steel products, as well as those concerned with non-ferrous metals.

The Solidification of Castings

Under this title the Institute has published, in the Monograph and Report Series (No. 7), a Review of the Literature prepared by Mr. R. W. Ruddle, M.A., A.I.M. The review is divided into two main sections, the first covering in a general way the work which has been done on the empirical application of scientific principles to the production of castings and ingots. The second part is concerned with the fundamental study of solidification rates and describes the work which has been carried out on mathematical analysis, pour-out methods, temperature measurement, and electrical-analogue methods of investigation. Although the first two methods have been employed mainly with steel castings it is shown that they are not entirely suitable for non-ferrous castings, but that the more recent methods show considerable promise.

A critical survey of the available data on thermal properties of metals and mould materials is given in an Appendix.

Copies of the Monograph may be obtained from the Secretary of the Institute of Metals at 4 Grosvenor Gardens, London, S.W.1 (price 10*s*. 6*d*. net).

NEWS OF SCIENCE AND INDUSTRY

National Coal Board Scholarships, 1950

In 1950 the National Coal Board will again offer up to 100 University Scholarships to give boys and young men the best education and practical experience that can be offered for the Mining Industry. Five scholarships will be allocated under a Scheme whereby ten Fuel Technology Scholarships are offered by the British Coking Industry Association.

Candidates from schools will be expected to have passed the Higher School Certificate Examination or the Senior Leaving Certificate of the Scottish Education Department and to have reached a high standard in mathematics and physics, and in chemistry, engineering, or geology.

Candidates from within the Industry should, normally, be under 25 years of age and must have reached university entrance standard, whether for a degree or a diploma, and they will normally be expected to have followed a part-time course at a technical college or similar institution.

Graduate candidates will be expected to have reached a sufficiently high standard in science or engineering to exempt them from two years of the honours course in an additional branch of engineering or science appropriate to the Industry.

All scholarships will provide for the total cost of the education and practical experience of the students over the whole year. In addition, maintenance allowances will be provided.

Application forms and a brochure containing further particulars may be obtained from the Director of Education, National Coal Board, Hobart House, Grosvenor Place, London, S.W.1. Application forms must be completed and returned to him not later than 15th April, 1950.

Applicants for awards to be made under the British Coking Industry Association's scheme of scholarships should write at once to F. Greenwell, Esq., 74 Grosvenor Street, London, W.1.

Applicants for these forms must state clearly whether they are still at school, already working in the Industry, or graduates applying to take further degrees.

Exhibition of Chemical Apparatus

The ACHEMA, an Exhibition covering the whole field of chemical apparatus, sponsored by the DECHEMA (Deutsche Gesellschaft für Chemisches Apparatewesen) will be held in Frankfurt-on-Main during the week 9th–16th July, 1950, in conjunction with a Meeting of that Society.

It may be expected that a whole series of new developments in the field of chemical apparatus will be submitted for discussion for the first time within the scope of this Exhibition and the Meeting held in connection with it. A large number of papers on the subject have been announced.

The following meetings will be held in Frankfurt during the Exhibition week: General Meetings of the Gesellschaft deutscher Chemiker, and of the Deutsche Gesellschaft für Chemisches Apparatewesen E.V.; and Special Meetings of the VDI-Fachausschuss für Verfahrengstechnik, of the Sicherheitsingenieure der Berufsgenossenschaft der Chemischen Industrie, and of the Verein Deutscher Eisenhüttenleute.

Joint Engineering Conference, 1951

The Councils of the Institutions of Civil, Mechanical, and Electrical Engineers have decided to hold, in London, a Joint Engineering Conference from 4th to 15th June, 1951, to coincide with the Festival of Britain.

The aim of the Conference will be to place on record the achievements of British engineers, and to afford an opportunity for engineers to discuss the development of sources of power in nature for the use and convenience of man. The Conference will underline the interdependence of all branches of engineering.

The Conference will also discuss the development of the system of education of engineers in Great Britain which, by the achievement of British engineers, has shown itself to be pre-eminently suited to the conditions in this country.

Institution of Mining and Metallurgy

Colonel L. C. Hill, D.S.O., M.C., A.R.S.M., Technical Adviser to the Rio Tinto Company, Ltd., has been elected President of the Institution of Mining and Metallurgy for the session 1950–51 and will take office at the Annual General Meeting, to be held on 18th May, 1950.

Technological Improvements and Vocational Training

The International Labour Office, Geneva, Switzerland, announce the issue of two new publications. The first, entitled "*Technological Improvements in the Iron and Steel Industry and their Effects on Employment*," discusses the plans for modernizing and expanding the iron and steel industry at present being pursued in various countries, and gives an account of the more important technological changes which have recently been introduced in the industry and the possible effects of these changes on employment.

The second, entitled "*Vocational Training and Promotion in the Metal Trades*," examines the nature and variety of the training facilities which are needed and the arrangements made in a number of countries for the recruitment of an adequate skilled force in the industry, and surveys the activities of the International Labour Organization in connection with vocational training in general. Both publications are on sale at 5*s*. each.

Research and Production Exhibition, 1950

The British Welding Research Association "Research and Production" Exhibition, which was held at the London headquarters from 7th–11th February inclusive, was considered by the Association to be a great success. A total of 1256 visitors viewed the Exhibition, including representatives of some 303 non-member firms. The total of 179 technical enquiries received during the course of the Exhibition are being dealt with by the staff of the Liaison Development Department.

The Exhibition was afterwards transferred to Glasgow and was shown at the Engineering Centre, Sauchiehall Street, from 20th–25th February.

New Welding Electrodes

Two recently developed welding electrodes have been announced, the first for depositing Monel metal and the second for depositing high-quality slag-free mild steel.

The Mirroid (New Type) electrode is suitable for welding Monel metal to mild steel, or to 18/8 stainless steel. It may be used in all welding positions and provides a deposit with good corrosion resisting and other physical properties.

The Pressure Vessel electrode, as its name implies, is designed for use on high-quality fabrications subject to searching radiographic examination. It is classified as E436 under the BEAMA–IOW Classification.

Both types of electrode have been developed by the Quasi-Arc Co., Ltd., Bilston.

Exactor Control Co., Ltd.

The name of this Company, specialists in hydraulic control and other equipment, and licencees of the Trabon system of centralized lubrication, has been changed to Exactor Ltd. The address and telephone number remain the same: 108 Park Street, London, W.1. Telephone: Mayfair 0252.

Henry Wiggin & Co., Ltd.

A post of Assistant Managing Director has been created by the Company, and Mr. John Hitchcock, B.Sc., personal assistant to the Managing Director, has been appointed to the new position. Mr. Hitchcock was formerly on the staff of the Development and Research Department of the Mond Nickel Company.

Flight Refuelling Ltd.

The Head Office of this Company is now at Tarrant Rushton Airfield, Nr. Blandford, Dorset. Telephone: Blandford 501.

MEMOIRS

Major **J. M. Campbell** was born in Glasgow in February 1893. He was educated at Wellingborough Grammar School and at Loretto. On leaving school in 1910 he spent some time in France and Spain learning the languages of those countries. During the 1914–18 war he served in the Royal Scots, first on the Western front, where he was mentioned in despatches and awarded the M.C. Later he served in Salonika, ultimately becoming Allied Representative in the Caucasus and gaining the O.B.E. (Military). In 1920 he returned to his father's business of iron ore merchanting and mining, and was responsible for the organization of large iron ore mines in Sierra Leone. In 1938 he was entrusted with the task of formulating a scheme for the import of iron ores into Britain in the event of war. On the outbreak of war he became Director of Foreign Ores (Iron and Steel Control) and put his schemes into practice. In 1942 he was made Deputy Controller for Raw Materials, from which post he resigned in 1943. He returned to the family business with his health seriously impaired, and he died suddenly at his home on 25th May, 1949.

Major Campbell was elected a Member of The Iron and Steel Institute in 1929.

Percy A. E. Armstrong died on 7th August, 1949, after a long illness. Although he was born and educated in England, he went to the U.S.A. 30 years ago. In that country he was recognized for his work in metallurgy, particularly as a leader in the development of stainless steels. He held more than 100 patents on alloy steels. Mr. Armstrong was a Vice-President and General Manager of the Allegheny Ludlum Steel Corporation, of Pittsburg, Pa. He became a Member of The Iron and Steel Institute in 1918.

Arvid H. Nilsson died on 28th October, 1949. He was born in Eskilstuna, Sweden, on 13th February, 1891. After matriculating, in 1909, from the Västerås Högre Allmänna Läroverk he undertook a year's studies at the Royal Technical College in Stockholm.

In 1914 Mr. Nilsson joined C. O. Ôberg and Companies, Aktiebolag, at Eskilstuna. He was appointed General Manager in 1923.

Mr. Nilsson joined The Iron and Steel Institute in 1927. He was also a member of the Metallographical Institute of Stockholm and was Past-President of the Swedish Tool and Metal Small Ware Manufacturers' Association and of the Metal Trades Employers' Association of Sweden. He was also a member of the Board of Directors of the General Export Association of Sweden, and of the Swedish Employers Confederation.

Vladimer Stieber died on 6th November, 1949. He was born in 1878, at Polska Ostrava, Silesia. After

receiving a general education he became a student in Pribram from 1896 to 1900. From then until 1904 he worked in the Vitkovice Steelworks. He then left for the U.S.A. and worked for two years as a draughtsman in Pittsburg, Pa. He returned to Europe in 1906 and became an engineer in the Kapfenburg Steelworks in Styria. In 1913 he was appointed Director of the Hrádek Steelworks in Bohemia. Fifteen years later, in 1928, he became Director of the Skoda Works in Pilsen. He was then appointed General Consultant to the Skoda Works in Prague, in 1933.

Ing. Stieber became a Member of The Iron and Steel Institute in 1930.

J. W. Summers died on 14th November, 1949, after a short illness. He was born on 26th September, 1893, at Stockton-on-Tees. After being for some years on the Engineering Staff of the Cargo Fleet Iron Company and the Skinningrove Iron Company, he joined the Engineering Staff of Messrs. Pease and Partners, in 1922, as a draughtsman in their Normanby Iron Works. He was subsequently promoted to the position of Chief Engineer, and in this capacity he was responsible for many schemes of reconstruction, including the post-war plans of the British Iron and Steel Federation. Mr. Summers became a Member of The Iron and Steel Institute in 1944.

Dr. **Fritz Meyer** died on 21st November, 1949. He was born in March, 1899, in Winterthur, Switzerland, and he received his early technical education at the Winterthur Technical College.

After matriculating, he proceeded to the Technical University at Aachen where he acquired his Diploma as Engineer. He then obtained the degree of Doctor of Engineering and later undertook consulting work for a number of large concerns in the U.S.A., for a period of seven years. He returned to Winterthur in 1934, and in 1936 he succeeded his father as Director of the foundries of Messrs. Sulzer Brothers, Ltd., Winterthur. During the war Dr. Meyer was a member of numerous committees engaged on problems connected with economic questions and, in particular, with the supply of raw materials for his country.

As well as being a Member of The Iron and Steel Institute from 1939 he was a member of the Institute of Metals, the American Foundrymen's Association, the Association Technique de Fonderie, the Société Suisse des Ingénieurs et des Architectes, the Verein Deutscher Giessereifachleute, and the Verein Deutscher Eisenhüttenleute.

Carl Hugo Carlsson died on 22nd December, 1949. He was born on 21st May, 1868, at Liden, a small country parish in the North of Sweden. After studying as a chemist at the Technical School at Örebro he became Chief Chemist at the Forsbacka Steelworks in 1886. In the following year Mr. Carlsson left Sweden for the U.S.A. where, from 1888 to 1899, he was engaged in several steelworks as Chemist or Chief Chemist. He crossed to Canada in 1899, and for five years was Superintendent of the open-hearth furnace plant at Sydney. He returned to Sweden in 1904 and for a year he acted as Consulting Metallurgist at Jernkontoret, Stockholm.

Mr. Carlsson joined the Fagersta Steelworks in 1905 as Superintendent of the open-hearth furnace plant and retained this position until 1913, when he was appointed General Superintendent. He was appointed Manager and elected to the Board of the Fagersta Steelworks in 1917, retaining these positions until his retirement in 1924.

His long association with The Iron and Steel Institute commenced in 1904. He became a member of the Verein Deutscher Eisenhüttenleute in 1910, and was also a member of several Swedish societies.

DIARY

3rd Apr.—SOCIETY OF ENGINEERS—"*Some Aspects of Gas Supply*," by E. C. Lejeune—Geological Society, Burlington House, London, W.1, 5.30 P.M.

3rd Apr.—CLEVELAND INSTITUTION OF ENGINEERS—"*From Ore to Tube at Corby*," by D. C. Hendry—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

4th Apr.—INSTITUTE OF METALS (London Local Section)—Discussion on "*Creep*," opened by Dr. N. P. Allen—4 Grosvenor Gardens, London, S.W.1, 7.0 P.M.

12th Apr.—INSTITUTE OF WELDING (West of Scotland Branch)—Annual General Meeting. "*Welding in the Construction of Hydro-Electric Plant*," by J. Crawford—39 Elmbank Crescent, Glasgow, 7.00 P.M.

14th Apr.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—Discussion on "*Residuals in Steel Casting*,"—39 Elmbank Crescent, Glasgow, 6.45 P.M.

15th Apr.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Annual General Meeting and Film on "*Chainmaking*," by Messrs. The Parsons Chain Co., Ltd.—Central Library, Swansea, 6.30 P.M.

17th Apr.—CLEVELAND INSTITUTION OF ENGINEERS—"*Chainmaking*," Film by Messrs. The Parsons Chain Co., Ltd.—Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, 6.30 P.M.

20th Apr.—INSTITUTE OF WELDING (N.E. Tees-side Branch)—"*The Use of Radiography in Weld Examination*," by E. Blakeborough—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.30 P.M.

25th–28th Apr.—THE INSTITUTE OF WELDING—Conference of Branch Officers, and Spring Meeting, Birmingham.

26th–27th Apr.—IRON AND STEEL INSTITUTE—81st Annual General Meeting—4 Grosvenor Gardens, London, S.W.1, 10.0 A.M.

26th Apr.—IRON AND STEEL INSTITUTE—Special Commemorative Lecture on Sidney Gilchrist Thomas, by J. Mitchell, 4 Grosvenor Gardens, London, S.W.1, 8.30 P.M.

27th Apr.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Solid, Liquid, and Gaseous Fuels*," by K. H. Wright, H. R. Hems, and M. Rodden—Victoria Hotel, Wolverhampton, 7.0 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the March, 1950, issue of the *Journal*, p. 354.)

TRANSLATION AVAILABLE

No. 396 (French). E. ROUSSEAU: "Determination of the Resistance to Erosion and Slag Attack of Steel Ladle Bricks." (*Chimie et Industrie*, 1949, vol. 62, Sept., pp. 243–248; Oct., pp. 362–370). (Abridged translation prepared by Mr. R. Sewell, and made available through the courtesy of the Research and Development Department of The United Steel Companies, Ltd., Stocksbridge, near Sheffield.)

CHARGES FOR COPIES OF TRANSLATIONS—The charge for the above translation is £1 for the first copy and 10*s*. for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

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MINERAL RESOURCES

Activities of the Spanish Iron and Steel Institute, July to September, 1949. (Instituto del Hierro y del Acero, 1949, vol. 2, July–Sept., pp. 42–51). [In Spanish].

At the meeting of the Iron-Making Division on July 14, 1949, the main report was on the result of the investigations of the iron ore deposits of Biscay and Santander. The first part stresses the necessity of checking previous work. These regions have long provided first-class ore, but detailed geological investigation by sounding has been lacking. In 1910, 71 million tons were estimated for the Vizcaya ores. Over 73 million tons have been mined to date.

The Spanish Iron and Steel Institute plans to study all Spanish iron ore deposits and their beneficiation, and it has agreed to start with those of Vizcaya and Santander.

These hematites are produced by the natural oxidation of the carbonates and occur in the upper zones of the deposits where atmospheric agents have been at work. It is unlikely that there are any surface deposits not known today, but the present investigations should prove the continuity of the known masses and may lead to the discovery of other deposits scarcely suspected. These will be, however, deep deposits consisting solely of carbonates. The exploitation of the mines in some of the richest districts will cause serious difficulties due to their proximity to the municipal and urban districts of Bilbao.—R. S.

Chromite Deposits near Seiad and McGuffy Creeks, Siskiyou County, California. F. G. Wells, C. T. Smith, G. H. Rynearson, and J. S. Livermore. (United States Geological Survey, 1949, Bulletin 948-B).

Manganese Resources of the Artillery Mountains Region, Mohave County, Arizona. S. G. Lasky and B. N. Webber. (United States Geological Survey, 1949, Bulletin 961).

Coal Deposits of the Santa Clara District near Tonichi Sonora, Mexico. I. F. Wilson and V. S. Rocha. (United States Geological Survey, 1949, Bulletin 962-A).

Manganese Deposits of the Serra do Navio District Territory of Amapá, Brazil. John van N. Dorr II, C. F. Park, jun., and G. de Paiva. (United States Geological Survey, 1949, Bulletin 964-A).

ORES—MINING AND TREATMENT

Beneficiation of Iron Ore. G. J. Holt. (Blast Furnace and Steel Plant, 1949, vol. 37, Sept., pp. 1061–1066). The author describes the iron ores of the Lake Superior district, the Michigan and Wisconsin districts, the Birmingham district, and other less important areas, and the types of beneficiation suitable for each type of ore.—J. P. S.

Ore Agglomeration and Red Mud Utilization in the Diósgyör Blast-Furnace Plant. (Bányászati és Kohászati Lapok, 1949, vol. 4, Aug., pp. 352–353). [In Hungarian]. The main feature of the new plant installed at Diósgyör for the preparation and agglomeration of iron ore is that the crushed ore is mixed with moistened 'red mud' which acts as a binder. The mass is briquetted and the bricks are fired at 1100° C. The burned bricks have a large number of cracks, and are very porous. The press produces bricks of 140 × 310 mm. section, each brick weighing 10–12 kg. The bricks are burned in two tunnel kilns, each 93 m. long. Blast-furnace gas is utilized as fuel in specially designed burners. The plant is intended to save the import of 10,000 tons of iron ore per annum.—E. G.

FUEL—PREPARATION, PROPERTIES, AND USES

Briquetting of Lignite and Coal Without Use of a Binder by the Dolni Rychmov Method. J. Formánek. (Bañský Obzor, 1949, vol. 3, Aug., pp. 121–123). [In Czech]. The method described is based on activation and stabilization of the tar products contained in the coal. This method has been used in an experimental briquetting plant for Sokolov lignite and it was completely successful during the last three years. The method is applicable to lignite, bituminous coals, and anthracite.—E. G.

The "Still" Coke Oven. D. Bagley. (Coke and Gas, 1949, vol. 11, Aug., pp. 265–270). The principles of the Still coke oven and some actual installations are described with notes on production, efficiency, and costs. The dimensions of the oven are 41 ft. long between doors, 19 ft. 8 in. high, 17¾ in. mean width; each chamber holds 28·2 metric tons of coal containing 10% moisture; with a coking period of 20 hr. the daily throughput is about 33·8 tons of moist coal per oven. The main characteristics of the design are the unusual height and the multi-stage heating system which secures almost complete uniformity of the heat intensity over the whole height of the chamber wall. Higher thermal efficiency and an increase of 15 to 21% in the yield of by-products are obtained compared with ovens 13 ft. high.—R. A. R.

Carbonizing Properties of No. 5 Block-Bed Coal from No. 5 Mine, Montcoal, Raleigh County, W. Va., and of Pocahontas No. 6 Bed Coal from Birdseye Mine, Sewell, Fayette County, W. Va. J. D. Davis, D. A. Reynolds, R. E. Brewer, D. E. Wolfson, and W. H. Ode. (United States Bureau of Mines, 1949, Technical Paper 711).

Carbonizing Properties of Beckley-Bed Coal from Stanaford No. 1 Mine, Mount Hope, Raleigh County, W. Va. J. D. Davis, D. A. Reynolds, R. E. Brewer, D. E. Wolfson, W. H.

Ode, and G. W. Birge. (United States Bureau of Mines, 1949, Technical Paper, No. 712).

Investigation of Coal Deposits in the Fairview and Coal City Basins, Coosa Field, St. Clair County, Ala. A. L. Toenges, L. A. Turnbull, T. R. Jolley, J. J. Shields, H. L. Smith, H. J. O'Donnell, H. M. Cooper, R. F. Abernethy, B. W. Gandrud, H. L. Riley, and H. E. Rothrock. (United States Bureau of Mines, 1949, Technical Paper, No. 719).

Reserves, Petrographic and Chemical Characteristics, and Carbonizing Properties of Coal Occurring South of Dry Fork of Minnesota Creek, Gunnison County, near Paonia, Colo., and the Geology of the Area. A. L. Toenges, J. J. Dowd, L. A. Turnbull, J. D. Davis, H. L. Smith, and V. H. Johnson. (United States Bureau of Mines, 1949, Technical Paper, No. 721).

Tracer Techniques in Study of Coke Sulfur. S. E. Eaton, R. W. Hyde, and M. H. Rood. (Analytical Chemistry, 1949, vol. 21, Sept., pp. 1062–1066). Radio-active sulphur in the elemental form was converted to radio-active iron pyrites (FeS_2) and mixed with the ingoing contents of a coke oven. The sulphur in the gas and in the coke was sampled and reduced to the elemental form again ; its activity was then re-measured. Results indicated that both the pyritic and the organic sulphur remain in the coke after coking and that, therefore, a low total sulphur is essential in coal intended for making metallurgical coke.—J. P. S.

Working Group on the Dry Cooling of Coke. (Ministry of Fuel and Power, Oct., 1948). Evidence taken from the operators and manufacturers of dry cooling plants in the United Kingdom indicates that the equipment can give reliable service provided it is adequately maintained. Dry cooling does not show any outstanding economic attraction for new or existing installations of horizontal and intermittent vertical retorts at gas works. The economic advantages and the fuel economy arising from the adoption of dry cooling with an anticipated production of approximately 1000 lb. of steam per ton of coke cooled are sufficient to warrant close consideration being given to the installation of dry cooling plants.—R. A. R.

Dry Coke Cooling. G. E. Foxwell. (Institute of Fuel and Iron and Steel Institute Joint Meeting, Nov. 18, 1949, Reprint). The economic and technical aspects of the dry-cooling of coke are considered and recent publications on this subject are critically examined.—R. A. R.

The Solid-Gas Heat Exchange Process. A. V. Brancker. (Chemistry and Industry, 1949, May 28, pp. 343–347 ; June 4, pp. 362–364). A mathematical investigation is made of the problem of heat transfer between a solid and a gas where no chemical reactions occur, with special reference to the continuous counter-flow process of dry-cooling coke.—R. A. R.

The Coking Heat in High-Temperature Gasification in Intermittently Operating Coke Ovens. R. Tettweiler. (Gas- und Wasserfach, 1949, vol. 90, Jan. 31, pp. 25–32 ; Feb. 15, pp. 68–69 ; Feb. 28, pp. 73–78 : [Abstract] Monthly Bulletin of the British Coal Utilisation Research Association, 1949, vol. 13, Aug., p. 272). The heats for coking for nine different Ruhr coals of volatile contents of 20% to 36% are derived by the construction of thermal balances from data from large-scale carbonization.

Large Increase in the Use of Anthracite by the Iron and Steel Industry. (Anthracite Institute Bulletin, 1949, June 15, p. 1 : [Abstract] Monthly Bulletin of the British Coal Utilisation Research Association, 1949, vol. 13, Aug., p. 272). Increased blending of anthracite with good coking coals to economize in the use of the latter led to a threefold increase in anthracite consumption by the U.S. steel industry from 1947 to 1948. Up to 5% is used in the blend.

Utilisation of By-Product Gases Aid to Fuel Conservation in the Iron and Steel Works. F. Kennedy. (United Nations Conference on the Conservation and Utilization of Resources, Lake Success ; Iron and Coal Trades Review, 1949, vol. 159, Oct. 21, pp. 949–951). The author emphasizes the need for the efficient utilization of the large quantities of by-product gases produced in a modern iron and steel works. He indicates the fundamentals in any good gas distribution system and examines the various potential gas-consuming units, *i.e.*, coke ovens, hot-blast stoves, soaking pits, mill re-heating furnaces, open-hearth furnaces, and gas engines, with a view to determining what particular fuels are most suitable to their needs and their subsequent effect upon the overall gas balance of the works.

Utilization of Coke Dust in Cupolas. (Bányászati és Kohaszati Lapok, 1949, vol. 4, Sept., p. 401). [In Hungarian]. It is proposed by B. Körös to briquette coke dust and other waste coke with an organic binder and use the briquettes for fuel in the cupola and drying stoves. The binder contains 5% of Portland cement and 1% of lime.—E. G.

The Properties of Producer-Gas Tars. S. M. Prasad, G. H. Thompson, and H. J. Hodsman. (Chemistry and Industry, 1949, Sept, 17, pp. 652–653). The tars obtained in three modern producer-gas plants furnishing clean washed gas, have been compared with normal gasworks tars. The general properties of the tars were surveyed. The total oils, although similar in quantity, differed in chemical character. The tar acids were not only large in quantity, but also yielded, after chlorination, a product of high bactericidal effectiveness.

Fluorescent Method for the Determination of the Cracking of Coke. B. A. Onusaitis and N. P. Iurevskaya. (Zavodskaya Laboratoriya, 1949, vol. 15, Aug., pp 955–956). [In Russian]. The study of the internal cracks of coke by the ultra-violet fluorescent method is described. The dried sample of coke was treated with a concentrated solution of anthracene in benzene, dried for several hours, and treated with chalk. The coke was then broken and the pieces were observed by ultra-violet light. The normal fluorescence was exhibited by those portions which had formed the surfaces of internal cracks, the original surface fluoresced with a dark red colour because of the chalk treatment and the portions which consisted of surfaces newly formed during the breaking process remained dark.—S. K.

Offering, Ordering, and Accepting Gas Producers. G. Neumann. (Stahl und Eisen, 1949, vol. 69, Aug. 4, pp. 561–562). The author regrets the lack of information on weights and thicknesses of components of gas producers when offers are submitted, and suggests that an agreed form of specification should be drawn up so that there would be a fair basis for comparison.—R. A. R.

Some Developments in Gas Producers. (Coke and Gas, 1949, vol. 11, Aug., pp. 273–277). Recent research work on gas-producer operation is discussed with special reference to that of H. L. Saunders and R. Wild, M. L. Hughes, and J. E. de Graaf. It was concerned mainly with the effects of segregation and channelling in the fuel bed.—R. A. R.

Cold Producer Gas, Especially from the Gasification of Brown Coal Briquettes. K. Guthmann. (Stahl und Eisen, 1949, vol. 69, Aug. 4, pp. 543–552). The report covers the recent developments in the design and operation of gas producers for the production of very clean cold gas, with special reference to the gasification of brown coal briquettes. Electrostatic methods of gas cleaning and for removing tar and oil are described. The distillation of tar and tar oils to produce lubricating oil and fuels for internal combustion engines is also dealt with.—R. A. R.

Long-Distance Gas—A Problem for the Iron Industry. W. A. Guldner. (Stahl und Eisen, 1949, vol. 69, Aug. 4, pp. 535–543). The manner in which the consumption of gas and electricity has developed in Germany is examined and the importance of coke-oven gas and long-distance gas under German post-war conditions is studied.—R. A. R.

Evaluation of the Performance of Gas Producers on the Basis of Slag Analysis. B. Selmeczi. (Bányászati és Kohászati Lapok, 1949, vol. 4, July, pp. 293–296). [In Hungarian]. The author analyses the various factors affecting the loss due to unburned combustible particles in gas producers. The paper includes graphs on the relation between the percentage of combustible particles in the slag and the ash contents of the coal used, and also between the percentage of the unburned particles in the slag and the load on the producer. A nomogram for determining the coal losses in the producer as a function of the percentage of combustible particles in the slag, and the ash and moisture contents of the coal are also given.—E. G.

Electrical Precipitation and Mechanical Dust Collection. W. A. Schmidt. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2428–2434). The fundamentals of the Cottrell electrical precipitation process are reviewed with notes on the effect of the resistivity of the dust and its dependence on temperature, humidity, and chemical composition. The importance of good gas distribution is emphasized and it is shown that proper distribution can be obtained by carefully chosen correction devices. Centrifugal dust collectors are also dealt with.—R. A. R.

Development of the Venturi Scrubber. W. P. Jones. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2424–2427). Venturi scrubbers for cleaning gas are described with special reference to the Pease-Anthony venturi scrubber. An installation for cleaning gas from open-hearth furnace, which, due to oxygen injection, carries a dense red smoke of iron oxide, is described.—R. A. R.

TEMPERATURE MEASUREMENT AND CONTROL

Some Basic Concepts of Thermoelectric Pyrometry. C. C. Roberts and C. A. Vogelsang. (Industrial Heating, 1949, vol. 16, Oct., pp. 1754–1756, 1900–1908). The theory governing the application of thermoelectric circuits to pyrometry is discussed with brief explanations of the Peltier and Thomson effects and the laws relating to intermediate temperatures and interconnected metals. Some methods of connecting thermocouples to measure temperature differences and average temperatures are given.—R. A. R.

Split Thermocouples. A. Searby. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., p. 36). Tests were made to determine whether steel bath temperatures could be measured by allowing the thermocouple leads to protrude from the furnace lining at some distance apart so that the molten charge formed the hot junction. The use of platinum/platinum–rhodium thermocouples without suitable protection from the molten metal is not practicable as the rate of solution is too rapid. Contaminants were found to have diffused back 1¼ in. along the wires in an immersion time of 60 sec.
R. A. R.

Corrigenda

In the September, 1949, *Journal*, p. 92, col. 1, last abstract, the second author's name, N. J. Grant, was omitted.

Fracture Characteristics of Ship Plate in Certain Small-Scale Tests. E. P. Klier, F. C. Wagner, and M. Gensamer. (Welding Journal, 1949, vol. 28, Feb., pp. 50-s–66-s). In the abstract of this paper published in the July, 1949, *Journal*, p. 365, the first sentence should have read as follows: "Notch-bar tests were carried out on a modified form of specimen in which the compression zone was drilled out and the hole filled with a hardened steel pin against which the load was applied."

This form of test-piece, devised by H. M. Schnadt, has been described by J. A. Haringx, (Ingenieur, 1946, vol. 58, pp. MK 15–17; Philips Research Report, 1947, vol. 2, Oct., p. 400). *See* Journ. I. and S.I., 1948, vol. 160, p. 332.

In the February, 1950, *Journal*, p. 256, col. 2, the first author of the book "Chemische Spektralanalyse" should have read "SEITH, W."

A Very Simple Temperature Regulator for Laboratory Furnaces. M. M. Noskov. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1257–1258). [In Russian]. A simple apparatus for the regulation of the temperature of laboratory furnaces to within 0·5–1° C. is described; in this the thermal expansion and contraction of a stretched Nichrome wire are mechanically amplified and used to actuate a system of relays.—S. K.

Automatic Combustion and Temperature Control on Modern Oil-Fired Furnaces. G. J. Jonas. (Industrial Heating, 1949, vol. 16, Oct., pp. 1758–1760). Recommendations are made on the control of burners for furnaces fired with heavy fuel oil. Individual oil-air proportioning settings for each burner and circulation of the oil through each burner to give it a uniform temperature and viscosity are advocated.—R. A. R.

On a Method for Determining the Lack of Balance of Alternating-Current Bridges. L. A. Goncharskii and A. F. Goncharskaya. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1259–1261). [In Russian]. Apparatus and circuits are described for measuring and continuously recording the out-of-balance of A.C. bridges such as are used for the determination of temperature, deformation, or the conductivity of electrolytes in industry.—S. K.

REFRACTORY MATERIALS

Petrographic Characteristics of Basic Chrome Magnesite Refactory Masses. D. S. Belyankin and B. V. Ivanov. (Ogneupory, 1949, vol. 14, No. 2, pp. 51–58 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 210). This is a critical review of the literature.

Refractories from Ukrainian Kaolins. L. E. Krushel. (Ogneupory, 1949, vol. 14, No. 1, pp. 40–46 [in Russian]: American Ceramic Abstracts, 1949, Sept., pp. 210–211).

Stratified Density of Refractory Bodies during Pressing. R. Ya. Popil'skii and A. V. Smolya. (Ogneupory, 1948, vol. 13, No. 11, pp. 507–515 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 211).

Manufacture of Grog and Grog-Silicon Carbide Shapes for Tubular Recuperators. Ya. L. Rigberg, M. S. Ivashchenko, and S. A. Gal'perina. (Ogneupory, 1945, vol. 13, No. 12, pp. 531–542 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 210). Details are given of the technology of the manufacture of grog and grog/silicon-carbide shapes for recuperators in rolling-mill furnaces. The grog charge consisted of clay 20%, kaolin 20%, and grog 60%; the grog/silicon-carbide charge consisted of clay 40%, grog 21%, and silicon carbide 39%. Shapes were made by the plastic method because the plant was not equipped for casting. The casting method for producing tubes should be investigated, however, because of the difficulties involved in the production of thin-walled tubes with parallel surfaces by the plastic method of forming. Results are tabulated and the equipment illustrated.

Production of Dinas for the Arch of the Open-Hearth Furnaces. Yu. P. Sidorenko and K. K. Tomash. (Ogneupory, 1949, vol. 14, No. 2, pp. 77–84 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 210). Details are given of manufacture and quality control at the Dzerzhinskii Red Army works. Both crystalline and cementing quartzites are utilized. The stability of the brick was as high as 230 heats in 100-ton and up to 160 heats in 150-ton furnaces. A flow sheet is included.

Wear of Heat-Resistant Chrome Magnesite in the Arches of Electric Smelters. A. T. Kleinberg. (Ogneupory, 1949, vol. 14, No. 2, pp. 85–90 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 211). Studies were made of 4½ and 15-ton furnaces. The chief cause of wear is thermal shock. In the 15-ton furnaces, the absorption of iron oxides by the refractory is also an important factor. The iron oxide penetrates into the brick along the cracks in the chromite and causes a splitting of the grains which accelerates destruction.

Comparative Studies on Silica Brick. I. K. Fuwa and S. Ito. (Journal of the Japanese Ceramic Association, 1942, vol. 50, No. 589, pp. 8–14: American Ceramic Abstracts, 1949, Sept., p. 210). The following properties of 23 samples of commercial silica brick produced in Japan were determined: Breaking strength, compressive strength, water absorption, porosity, and apparent and true density. By microscopic observation of the samples, the percentage of quartz and cristobalite was measured.

Effect of Diabase on the Properties of Magnesite Refractories. A. S. Berezhnoĭ. (Ogneupory, 1949, vol. 14, No. 1, pp. 30–40 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 210).

Coke-Oven Dinas with Manganese Binder. I. S. Smelyanskii and V. D. Tsigler. (Ogneupory, 1949, vol. 14, No. 1, pp. 9–21 [in Russian]: American Ceramic Abstracts, 1949, Sept., pp. 209–210).

Coatings for Hot Repairs of Dinas Brickwork in Coke Ovens. A. A. Pirogov, L. A. Tseithin, and V. P. Rakina. (Ogneupory, 1948, vol. 13, No. 11, pp. 492–502 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 209).

Heat Resistance of Refractory Materials. N. V. Solomin. (Steklo i Keram, 1949, vol. 6, No. 1, pp. 8–9 [in Russian]: American Ceramic Abstracts, 1949, Sept., p. 210). Instead of the standard methods for determining refractoriness, the author proposes the use of his viscosimetric method in which the rate of deformation (inverse of viscosity) under constant temperature and load is measured and the results are expressed in poises. The greater the viscosity, the greater is the resistance to high temperature under load. By plotting log of viscosity against temperature, a practically straight line is obtained. The method has been in practical use since 1941; examples are described.

The CaO–MgO–Cr_2O_3 Ternary System. Part III—The CaO–CrO_3–Cr_2O_3 Ternary and the MgO–Cr_2O_3 and CaO–MgO Binary Systems. W. F. Ford and J. White. (British Ceramic Research Association: Transactions of the British Ceramic Society, 1949, vol. 48, Nov., pp. 417–427). A detailed study

of the dissociation of calcium chromate *in vacuo* has confirmed the phase distribution in the $CaO–CrO_3–Cr_2O_3$ ternary system previously suggested. The ternary complex compounds in the system are: (1) $9CaO.4CrO_3.Cr_2O_3$; (2) $6CaO.2CrO_3.Cr_2O_3$; (3) $3CaO.2CrO_3.2Cr_2O_3$; and (4) $4CaO.CrO_3.Cr_2O_3$. Under normal heating conditions in air, only compounds (1) and (3) are probable products. Chromic oxide dissolves to a negligible extent in picrochromite in the solid state. Evidence for an appreciable solid solubility of magnesia in lime at high temperatures has been found.

The Relation between Refractory Life and Refractoriness. W. J. Rees. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, p. 5). Factors affecting the life of refractories in cupolas and converters are discussed. The author favours evaluating refractoriness by a test under a relatively light load. In the case of a mixture of two grades of ganister and a clay bond, a series of tests on mixtures in different proportions can be made and an equilibrium diagram constructed. The density obtained with a rammed lining depends greatly on the grading; one which gives good results is 45 parts of coarse, 10 parts of 'middles,' and 45 of fines.—R. A. R.

The Performance of Various Monolithic Converter Refractories. J. L. Harrison. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 6–7). Tests of the performance of three unnamed materials, with different characteristics, as linings for an oval converter with axes of 4 ft. and 2 ft. 10 in. are reported and the results discussed. The averages of the carbon and manganese removed when plotted against the number of heats produced showed no really clear indication of the effects of these elements. As the carbon content decreases there is a tendency for lining life to increase slightly, and the reverse appears to be true of the manganese. On the whole, lining life increases with increase in the time spent drying out the lining, and the higher its thermal conductivity. R. A. R.

Laboratory Investigations of Used Monolithic Converter Materials. P. Murray. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 8–14). Samples from used silica monolithic and brick linings from converters have been analysed and tested and their properties compared with those of the new materials. Two entirely different types of attack on materials of low vitrification temperature and of high refractoriness are involved. In the former, fusion of the material independently of, and ahead of, flux penetration in effect restricts the attack to a surface one, thus slowing down chemical attack in spite of the inferior refractory properties of the material. The relatively pure, highly refractory type of material permits flux penetration and attack in depth much more readily; it relies for reasonable life on its higher refractoriness and the fact that it requires a greater percentage of flux to liquefy it at working temperatures. It seems fairly certain that in side-blown converters and ladles the highly viscous nature of the fused layer and the steep temperature gradients arising from the intermittent nature of the process are important factors in the durability of material of low refractoriness.—R. A. R.

Experience with Basic Bessemer Refractories. D. Bird. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, p. 15). Lining practice for 25-ton basic-Bessemer converters at the steelworks at Corby is described. For the shallower bath of metal now blown the lining wall starts at 34 in. thick and quickly steps back in 3-in. set-backs to 22 in. made up of two 9-in. courses of semi-stabilized dolomite bricks with 4 in. of dolomite ramming behind. The recent average life has been 223 blows per lining and this with more silicon in the iron than formerly. If an 18-in. brick could be supplied the life would be appreciably increased.—R. A. R.

Refractory Wear and Converter Design. M. P. Newby. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 16–20). Flow paths of the blast have been studied in a transparent model of a side-blown converter using air blown on to water and air entrained in water blown on to plasticine. Greatest erosion takes place opposite the tuyeres and between the tuyeres. A proposed design for preventing the back eddy from coming in contact with the walls consists of a converter, circular in section, with two sets of tuyeres more or less diametrically opposite each other, tilted about 15° from the centre of the chamber so that the blast going in is given a swirl which continues up to the nose.—R. A. R.

Cupola Refractories—A Review of the Literature. W. A. Archibald. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 23–31). A review of the literature on cupola refractories reveals general agreement on many points, some of which are: (1) The melting zone is the position of most serious wear, but little attention is given to the possibilities of mechanical wear in this zone; (2) it is preferable to chip away the slagged layer before patching; (3) the initial lining material is of less importance than the patching material, except to support the latter in place; (4) the extra cost of basic refractories is not an economic proposition unless the desulphurizing and dephosphorizing reactions are specially required; (5) balanced blast makes the wear more uniform; (6) extensive water-cooling at the melting zone causes greater consistency of working; and (7) heating the blast by the waste gases increases efficiency but affects the refractories and is likely to encourage more research on water cooling.

Some French Developments in Cupola Linings. M. P. Nicolas. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 32–33). French research on the improvement of ganister linings for cupolas is reported. The conclusions are: (1) The ganister should contain 7–9% of alumina; (2) A.F.A. (American Foundrymen's Association) index should be close to 60, with about 25% of the grains between 1·5 and 5 mm.; (3) the clay binder should contain a minimum of fusible constituents, *i.e.*, less than 0·20% MgO, 0·80% CaO, 0·50% alkalis, and 1·00% Fe_2O_3; (4) a ramming technique must be developed and adhered to; (5) the lining must be allowed to dry out for eight days before firing; and (6) initial heating must be very gradual.—R. A. R.

Refractories for Bessemer Steel Foundries in Germany. K. J. F. Klein. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 34–35). Current practice and results with silica refractories in German foundries using cupolas and converters are presented. The quality of rammed linings has not yet reached that of linings in 1939.—R. A. R.

Developments in Foundry Refractories. G. R. Rigby. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 39–41). The stabilities of quartz, tridymite, and crystobalite are discussed and the significance of van Praagh's work on the growth of quartz crystals under hydrothermal conditions is pointed out. Van Praagh has found that by heating silica glass in a steel bomb with water at about 450° C. he could obtain the high-temperature form of cristobalite which survived at room temperature. If this form can be stabilized it would be possible to produce a brick comparatively free from spalling.

An alumina content of about 4% is recommended for ramming mixes; this can be achieved by introducing about 9% of clay which must be naturally plastic.

Another development is the possibility of using no clay at all and substituting the so-called silicon esters. Silicon ester is a liquid which will hydrolyze with water and by adding alcohol to the water the hydrolysis can be controlled, so that, after a given period, silica is deposited as a stiff silica gel which can be prepared in a mould, slowly dried, and fired in the usual way.—R. A. R.

The Relining and Patching of Converters and Cupolas. H. Parnham. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 42–43). Recommendations are made on the quality of acid ramming material and the ramming technique. The importance of good grading, proper storage, preparation with the optinium moisture content before use, ramming, venting, and drying are stressed.—R. A. R.

The Drying of Refractories. B. Vassiliou. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 44–47). The factors governing the rate of removal of moisture in drying operations are considered and curves showing changes in moisture content at increasing distances from the surface of clay are presented. Drying of clay proceeds in two stages. In the first, moisture is removed at a constant rate per unit area of surface and the interstices between particles remain

filled with water ; this is accompanied by shrinkage approximately equal to the volume of water lost. The second stage begins when the rate of evaporation falls off with decreasing moisture content : in this stage evaporation is actually proceeding from levels beneath the surface.—R. A. R.

Future Trends in Cupola and Converter Operation. A. H. B. Cross. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 48–49). Based on the information brought out in the papers at this Conference the author discusses trends in cupola and converter operation. For cupolas the trend is towards thinner linings and water cooling. The development of carbon linings in the combustion zone of the cupola requires study. Shaping the interior of the cupola to simulate a small blast-furnace is receiving consideration. In the fine-grinding of refractory materials more knowledge is required on the fineness of the fines and it is not sufficient merely to state an upper limit. The consideration of drying leads to the idea of drying a converter lining from the outside.—R. A. R.

Laboratory Now in Service Combines Testing of Refractories with Research. C. Longenecker. (Blast Furnace and Steel Plant, 1949, vol. 37, Sept., pp. 1078–1080). The General Refractories Company has built a new laboratory at Baltimore, Md., for the chemical analysis of refractories, to which is attached a pilot plant for the manufacture and service testing of bricks.—J. P. S.

BLAST-FURNACE PRACTICE AND THE PRODUCTION OF PIG IRON

Stepped Tests on a Rapidly Heated Blast-Furnace Stove. M. Steffes. (Stahl und Eisen, 1949, vol. 69, Sept. 29, pp. 687–691). Data were obtained relative to the operation of a blast-furnace stove 32 m. high with an inside dia. of 7 m. and a checker area of 17,725 sq. m. of the rapid-heating type burning blast-furnace gas and air supplied under pressure. Quantities, pressures, and temperatures of blast-furnace gas, combustion air, and blast were measured by recording instruments at five blowing rates, namely, 30,000, 40,000, 50,000, 60,000, and 70,000 cu. m./hr., and a thermal balance was drawn up ; from this conclusions affecting the construction of the checkers are drawn.—R. A. R.

The 'Variable Turbulence' Stove and the Denain Trials. D. Petit. (Instituto del Hierro y del Acero, 1949, vol. 2, July–Sept., pp. 5–16). [In Spanish]. The first part describes the basic principles of the 'variable turbulence' blast-furnace stove. In 1942, the Denain-Anzin Company decided to apply the principle to two of their stoves. The second part gives results of the test at Denain and details of the vertical and horizontal distribution of temperature. The efficiency of the stove during May, 1949 varied between 90 and 91%.—R. S.

Wiberg-Söderfors Method for the Manufacture of Sponge Iron. Bo. Kalling and J. Stalhed. (Steel, 1949, vol. 125, Sept. 19, pp. 72–75, 102, 104, 106). The Wiberg-Söderfors process for the production of sponge iron is described in full. The ore in passing down the furnace is first preheated and its sulphur removed by the combustion, with extra air supplied from outside, of the gas from a separate producer. This gas has already done most of its work in reducing the ore lower down the furnace. The ore next comes into the prereduction zone where it is reduced from Fe_2O_3 to FeO, and to the final reduction zone where it is reduced to metallic sponge iron. At the top of the reduction zone, however, some of the gas, still containing carbon monoxide and hydrogen, passes to the producer, an electric arc furnace fed with charcoal. Reactions with the charcoal in the producer (or carburettor) reduce the carbon dioxide to monoxide and the water vapour to hydrogen and carbon monoxide ; some gas, however, continuously leaves the top of the furnace, taking hydrogen away as water vapour, so that the necessary restoration must be made by the addition of fuel oil or water to the carburettor. The sponge iron, with a degree of reduction ranging, according to the rate of working, from 84 to 95%, passes through a short cooling zone below the reduction zone, before discharge. In the case described, it is all used in the electric steel furnace. The possibilities of using various grades and sizes of ore are examined, and attempts to develop a carburettor using coke are described. The economics of the plant, in terms of power, charcoal, and electrode consumption per ton of iron produced, are also explained.—J. P. S.

The Influence of the Throat Diameter on the Behaviour of Fines in the Blast-Furnace. P. Reichardt. (Iron and Steel Institute, 1950, Translation Series, No. 391). This is an English translation of a paper which appeared in Stahl und Eisen, 1949, vol. 69, July 21, pp. 503–508 (*see* Journ. I. and S.I., 1950, vol. 164, Feb., p. 229).

Proposals for the Modification of a Blast-Furnace Top to Give Controlled Burden Distribution. E. L. Diamond. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 173–181). This paper embodies a practical engineering design for modifying an existing blast-furnace to give control of stock-line segregation by the method of a moving frustrum below the big bell, as proposed by Dr. H. L. Saunders. An alternative design, using a fixed frustrum, is also presented, which gives nearly as wide a range of control by a somewhat simpler method. The degree of control given by each design is examined in the Appendix.

Production of Pig Iron. B. M. Stubblefield. (Steel, 1949, vol. 125, Sept. 12, pp. 128–143 ; Sept. 19, pp. 88–98 ; Sept. 26, pp. 78–88 ; Oct. 3, pp. 84–94). The author first considers briefly the present position of the blast-furnace, both as producer of pig iron and as gas-producer and outlines its development to this state. He then deals with the iron ores of the United States, their composition and treatment, and passes on to the consideration of coke and of fluxes. Considering next the structure of the furnace itself, he describes its construction and the materials used from hearth to furnace top gear, giving special attention to refractories, hearth, and stack coolers. Methods of ore, coke, and flux storage are then dealt with ; a section on blast-furnace stoves follows, together with gas-cleaning methods. The author then passes on to a consideration of the chemistry of the blast-furnace process, and the behaviour of carbon, silicon, and manganese. In conclusion he touches upon the possibilities of oxygen-enriched blast and of high top pressure.—J. P. S.

The Influence of Gas/Solid Temperature Differences on Blast-Furnace Operation. J. Taylor. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 129–140). The effects of the major operating variables on gas/solid temperature differences in the stock column of the blast-furnace have been calculated. These data have been used in a consideration of the question of the extent to which the high-temperature heat requirement, as against total heat requirement, is an overriding factor in carbon efficiency. It is concluded that only for low slag volumes, low blast temperatures, and high hearth temperatures is this probably the case for modern furnaces. Even then the increase in carbon requirements is small, and conclusions drawn on the basis of the overall heat balance require little modification. The general effect of the operating variables on the vertical temperature gradient in the stack column has been deduced from the gas/solid temperature differences. It is considered significant that the same conditions known to give sticking and irregular stock movement give a steeper temperature gradient in the lower part of the furnace. The consequent downward displacement of the slag fusion zone, and possibly also of the carbon deposition zone, is believed to be the cause of this irregular stock descent. Lowering the blast temperature is the usual remedy, but this means sacrificing the theoretical carbon economy of high blast temperatures. Other methods of raising the slag fusion zone are considered, but only the addition of coke-oven gas is attractive from a technical point of view.

The Maintenance of Blast-Furnace and Ancillary Plant. A. Bridge. (Journal of The Iron and Steel Institute, 1948, vol. 159, June, pp. 193–204). The organization and functions of the blast-furnace maintenance department are considered, and the work entailed and the practice at the Appelby-Frodingham blast-furnaces on the following items are described : (1) Furnace maintenance, including repairs to hearth casing, top, bleeder assembly, and relining ; (2) stoves, and gas and blast mains ; (3) ore crushers and conveyors ; (4) sintering plant ; (5) descaling ; and (6) blowers.—R. A. R.

Electrolytic Iron. C. Tschäppät. (Schweizer Archiv, 1949, vol. 15, Aug., pp. 225–242). A description is given of a continuous electrolytic process for the production of pure iron sheets 0·05 to 0·3 mm. thick. The iron produced is characterized by its very low content of carbon (0·010%) and the absence of manganese ; the silicon, phosphorus, and sulphur contents are 0·001%, 0·012% and 0·003% respectively.

Extensive data on the mechanical, thermal, electrical, and magnetic properties are given.—R. A. R.

PRODUCTION OF WROUGHT IRON

Wrought Iron Has Two Components. (Industry and Power, 1948, vol. 55, Dec., pp. 88–89, 114: [Abstract] Metals Review, 1948, vol. 22, Jan., p. 24). Chief characteristics and two present-day methods of producing wrought iron are described.

PRODUCTION OF STEEL

Papers Read at the Conference of Mining and Metallurgical Engineers Held at Karlove Vary, May 22–24, 1947. J. Vodrážka. (Baňský Obzor, 1949, vol. 3, Oct., pp. 142–144). [In Czech]. The author summarizes the papers presented at the above conference. They were:

Rationalization of the Production and Utilization of High-Quality Steels, by I. Čerkesov.

The Importance of Rationalization with Particular Reference to the Metallurgical Industry, by J. Mayer. This dealt with the equipment and processes in blast-furnace, Bessemer, open-hearth, and electric-furnace installations, rolling-mills, foundries, and heat-treatment shops.

Measurement of Second Degree Internal Stresses, by P. Skulari. This paper discusses the X-ray measurement of internal stresses.

Examples of Research Work Carried Out in the Metallurgical Institute of the Acadamy of Science, U.S.S.R., by P. Sulari. Work on heat-resisting steels for high-pressure boilers is reported, and Croloy steel with a niobium addition is recommended.

The Ferrous Metal Industry in Germany during the Period 1939–1945. G. Patchin and E. Brewin. (British Intelligence Objectives Sub-Committee Overall Report No. 15, 1949: H.M. Stationery Office). Over 400 reports have been issued as a result of visits by some 120 teams of British and American experts to German works. In this volume these reports are correlated and condensed so that an exhaustive summary of the developments in the German iron and steel industry, surveyed from all angles, is presented.—R. A. R.

Study of the Blowing of a Basic Bessemer Converter by Means of an Integrating Flow Recorder. R. Michaux, P. Leroy, F. Meyers and F. Renard. (Société Française de Métallurgie, Oct. 4, 1949: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 779–796). The time required to blow a charge in a converter is largely determined by the rate at which the air can be introduced into the converter. From just after the start of decarburization till about the middle of this stage the danger of ejects limits the rate of blowing, but before and after this stage the power of the blower is the limiting factor. At the Homécourt Works in 1933 and later, tests were made to relate the duration of the blow to the quantity of blast blown from the commencement of the blow and to determine, as a function of this, the limiting rate of blowing during the blow beyond which ejects would appear. A **V**-curve relating the rate to the percentage of the total air volume required for the blow was obtained; its minimum was always at about one-third of the total air required and at about half the total air the curve rose so high that the power of the blower became the determining factor. The value of the minimum depended on whether the iron blew well or badly, and particularly on the silicon content. By adjusting the rate of blowing to conform to the curve an average saving of 2–3 min. per blow was gained. The importance of this subject led the authors to design and study an integrating flowmeter which records the instantaneous rate of flow of a fluid as a function of the total volume so far passed. The principles underlying the measurement of flow and the causes of error are explained, and then the apparatus itself and its design are described in detail. Finally, recorder charts obtained in practice at two steelworks by means of the integrating flow recorder are reproduced, their indications are analysed and their use in correcting blowing practice is explained.—A. E. C.

Structural Frames for Melting Shops. J. S. Terrington. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 195–222). A description is given of melting-shop designs which have been adopted in recent years in various parts of the country, and the salient features of these designs are reviewed and commented upon. The numerous requirements which must be met in good melting-shop design are examined. It is shown that the most suitable building material, the general dimensions of the shop, and a suitable type of construction can be determined. Ten new designs are proposed, incorporating most of the essential melting-shop requirements. The designs are purely functional, and the pleasing appearance of some of the schemes is due to good lighting and ventilation and unobstructed clear spans.

Concentrated Oxygen in Open Hearth Furnaces. W. Trinks. (Industrial Heating, 1949, vol. 16, Oct., pp. 1738–1740). The supply of oxygen to the open-hearth furnace by adding it to the air in the uptake, adding it at the burner, and blowing it into the bath is discussed. The first method is not recommended, and it is doubtful whether the second method will be continued when the high post-war demands for steel have been met. The third method may cause such a violent evolution of carbon monoxide that the furnace roof is damaged; this can be avoided by not injecting oxygen until the carbon has dropped to 1%.—R. A. R.

Desulphurization in the Basic Open Hearth Furnace Using Bauxite. L. Cook. (Blast Furnace and Steel Plant, 1949, vol. 37, Sept., pp. 1067–1068). In spite of views expressed to the contrary, the author claims that the use of bauxite to increase the fluidity of the slag does not hinder desulphurization. He bases this opinion on charges run at the Volta Redonda plant in Brazil and on cold charges containing a high proportion of cold scrap during a shortage of hot metal. Desulphurization was slightly faster when using bauxite in the flux.—J. P. S.

Scrap Charging—Key to Increasing Open Hearth Production. R. R. Fayles. (Blast Furnace and Steel Plant, 1949, vol. 37, Sept., pp. 1092–1098). Steps taken by the Lukens Steel Company to reduce the time of scrap-charging from about 5¼ to 4 hr. included careful study of purchased scrap, conditioning of home-produced scrap, special magnets and charging boxes, and modification of furnace doors to allow the charging of the largest possible pieces of heavy scrap such as broken mill rolls and ingot croppings.—J. P. S.

Some Fundamental Problems in the Manufacture of Steel by the Acid Open Hearth and Acid Electric Processes. G. R. Fitterer, J. W. Linhart, J. B. Kopec, and J. G. Bassett. (Acid Open Hearth Research Association Inc., 1949, Bulletin 2). This bulletin contains the following papers:

Some Fundamental Problems in the Manufacture of Steel by the Acid Open Hearth Process, by G. R. Fitterer (*see* Journ. I. and S.I., 1945, No. II, p. 161A).

Acid Electric Slags, by G. R. Fitterer (*see* Journ. I. and S.I., 1947, vol. 157, Dec., p. 634).

Control of Acid Open Hearth Heats through Measurements of Slag Fluidity, by J. W. Linhart (*see* Journ. I. and S.I., 1947, vol. 156, Aug., p. 575).

A Comparison of the Pt/Pt–Rh Thermocouple with the Optical Pyrometer for Temperature Measurements in Liquid Steel. G. R. Fitterer and J. W. Linhart (*see* Journ. I. and S.I., 1948, vol. 159, July, p. 322).

The Relation of Acid Open-Hearth Furnace Efficiency to Practice, by G. R. Fitterer, J. G. Bassett, and J. B. Kopec (*see* Journ. I. and S. I., 1949, vol. 163, Sept., p. 95).

Electrical Hazards in the Melt Shop. F. W. Brooke. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 3–16). An electric steel furnace installation with the secondary leads enclosed in heavy rubber hose carrying cooling water is described; these leads are of much smaller section than air-cooled leads carrying the same current, and safety to personnel is increased. The jamming of electrical interlocks to the circuit breaker is discussed and the fitting of an additional mechanical interlock is recommended. Insulation between live electrode and dead mast should be as near as possible to the mast, not right up to the electrode holder; insulation moulded under high pressure and temperature is recommended and the use of through-bolts insulated with ferrules is condemned. The danger of allowing dirt and ore dust to cause electrical leakage between electrodes where they pass through the furnace roof is stressed.—R. A. R.

Safety in the Melt Shop. W. D. Hitchcock. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 17–27). Safety equipment at the electric furnaces of the Carnegie-Illinois Steel Corp. is described. It includes ½-in. chain to electrode cooler rings to prevent them falling into the bath in the event of roof failure.—R. A. R.

Production of Composite Materials by the Electric Fusion Process. R. K. Hopkins. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 75–90). The Kellog process of producing composite slabs of carbon steel clad with alloy steel by fusing carbon steel electrodes and tubular electrodes through which the alloying materials (*e.g.*, ferrochromium) are supplied, to the surface of the carbon steel under the protection of molten flux has already been described (*see* Journ. I. and S.I., 1948, vol. 159, May, p. 88). An account is now given of its commercial development under the trade name of Pluramelt, together with the results of many tests on the rolled composite products which are called Kelcaloy. Square bars have been twisted cold more than 720° and heavy plates have been quenched 20 times from 1200° F. with water without cracking or separation taking place. The composition of the alloy steel cladding is very uniform throughout its thickness. The rate of heat transfer is much more uniform than in the case of a carbon steel vessel with an alloy steel lining intermittently welded to it. Data on the distribution of compressive and tensile stresses in a Kelcaloy pressure vessel at various temperatures are presented. This composite steel is intended for pressure vessels used in the refining of sour crude oils.—R. A. R.

The Electric Ingot Process. R. K. Hopkins. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 91–105). A machine for the continuous casting of alloy steel ingots by the Kellog process is described (*see* preceding abstract). Such ingots have no pipe and a smooth surface so that the yield is high. Results of tests for uniformity of analysis, micro- and macrostructure, and mechanical properties of 16/25/6 chromium–nickel–molybdenum steel for gas turbine wheels and shafts are presented.

High-speed steel milling cutters can be made direct from as-cast and annealed ingots produced by this process, which also lends itself to the production of stainless steel with additions of small amounts of lead to improve the machinability.—R. A. R.

The Kellog Electric Hot-Top Process. R. K. Hopkins. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 106–121). In the Kellog Electric Hot-Top Process heat is supplied to the top of metal in the ingot mould by the discharge of a controlled current from an electrode submerged in a protective blanket of flux. The equipment, which is described and illustrated, consists of a power source, and automatic control, an automatic head, a non-consumable liquid-cooled electrode assembly, and a circulating system for the coolant. The power consumption for all ingot sizes and grades tested over a long period varies between 20 and 40 kW./ton (2000 lb.), and the operating cost, including amortization, is about the same as when using refractory hot tops. The average yield in the production of rolled and of forged billets from ingots measuring $9 \times 9 \times 40$ in. using this process was 92·3%. Formulæ for calculating the economic advantages of the process are developed and their use explained.—R. A. R.

Use of Oxygen in the Manufacture of Basic Electric-Furnace Steels. J. E. Harrod. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 123–127). The manufacture of stainless steel, other alloy steels, and rimming steels in a 70-ton Héroult basic-lined electric furnace using the Chelius patent process is described. Oxygen is supplied through a lance pushed into the slag so that the gas is fed to the slag–metal interface. For stainless, alloy, and rimming steels the oxygen consumptions were 576, 164, and 58·5 cu. ft./ton respectively; no ore or scale has been used in this melting shop for more than two years. Greater recovery of chromium from stainless steel scrap is obtained.—R. A. R.

Use of Oxygen in the Manufacture of Electric-Furnace Steels. A. C. Ogan. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 127–129). Data are presented on the production of stainless steel in basic-lined Héroult electric furnaces using oxygen injected at 10,000–12,000 cu. ft./hr. through a ½-in. pipe. With the proper use of oxygen an increase in wall and roof life is obtained. With a 13-in. silica brick roof in a 20-ft. ring the life averaged 75 to 80 heats, about 95% of which were stainless steel. High-silicon scrap is used to make up the portion of the charge which is not stainless, some ore or mill-scale is added, and the oxygen injection is started when about 75% has melted.—R. A. R.

Use of Oxygen in Manufacture of Basic Electric-Furnace Steels. G. P. Michalos. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 130–140). Experience with the use of oxygen by the Timken Roller Bearing Co. for making nickel–molybdenum and high-carbon medium-chromium steels, as well as 16/25/6 nickel–chromium–molybdenum steel is reported. With the 16/25/6 alloy 386 cu. ft. of oxygen are used per ton and 77 cu. ft. for each 0·01% of carbon removed; the percentage recoveries in the finished alloy are chromium 58·3, nickel 81·7, and molybdenum 72·3. No appreciable amounts of nickel or molybdenum appear to pass into the slag.—R. A. R.

Relation between Chromium and Carbon in the Refining of Chromium Steel. D. C. Hilty. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 140–153). *See* Journ. I. and S.I., 1949, vol. 162, June, p. 231.

Use of High-Purity Oxygen for Decarbonization in Five-Ton Acid Electric Furnaces. C. Wyman, E. J. Goehring, and C. A. Faist. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 154–167). Data are presented and analysed on the results obtained with oxygen injection when making carbon steels and manganese steels in a 5-ton acid electric furnace. The main conclusions were: (1) Good results were obtained with oxygen at 60 lb/sq. in. through a ⅜-in. pipe. (2) Carbon was removed at 0·077%/min. with an oxygen flow of 135 cu. ft./min. (3) Bath temperature increased sharply when injecting oxygen even with the current shut off. (4) The metal was more fluid when using oxygen than when ore was added for reduction. (5) The physical properties of the castings were somewhat better than when ore was used. (6) The recovery of oxidizable alloying elements was markedly increased with oxygen injection.—R. A. R.

Use of Oxygen in Acid Electric Practice. R. H. Jacoby and M. Petty. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 168–170). An account is given of the results obtained with oxygen injection when making stainless steels in a small acid-lined electric furnace. The first series of trials was unsuccessful because oxygen injection was started before a sufficiently high temperature had been reached. The second trials were successful and savings of 14 kW./per ton were obtained when making 5% chromium 0·5% molybdenum steels.—R. A. R.

Use of Oxygen in the Melting of Stainless Steels for Castings. R. J. Wilcox. (American Institute of Mining and Metallurgical Engineers, Electric Steel Furnace Conference, Dec., 1948, vol. 6, pp. 170–174). This report on the use of oxygen when making 18/8 stainless steel in a 3½-ton acid electric furnace shows that about 496 cu. ft. of oxygen were used per ton of steel and 37·8 cu. ft. for each 0·01% drop in the carbon. Power consumption in kWh. was reduced about 20%, electrode consumption 15%, and man-hours 17%, whilst lining life was about the same as without oxygen. Larger proportions of alloy steel scrap could be charged.—R. A. R.

Complex Deoxidizers in Electric-Furnace Cast Steel. H. A. Young. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 189–194). A series of carbon–molybdenum steel melts was made in an acid-lined 1000-lb. induction furnace, using different combinations of silicon and manganese ferro-alloys with and without calcium- or selenium-bearing compounds for deoxidation, and Charpy impact tests were carried out at + 70°, −50°, and −100° F. on heat-treated specimens. In general, it was apparent that provided the steel was thoroughly deoxidized, the type of deoxidizer used was not particularly important.—R. A. R.

Use of Complex Deoxidizers. G. A. Lillieqvist. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 194–198). Steel castings of special design were made to study the relation between the deoxidizer added and the porosity and inclusions. In most cases aluminium in pure form or as an alloy was the best preventative for porosity. Normally, ¼ lb. of aluminium per ton of steel is sufficient, but more

than this is generally added. Calcium–manganese–silicon is sometimes used for special castings to control inclusions, particularly if the preliminary analysis shows sulphur to be rather high.—R. A. R.

Effects of Complex Deoxidizers on Silicon-Killed Steels, with and without the Addition of Aluminium. P. E. Eubanks. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 199–207). An investigation of the porosity, microstructure, and tensile and impact properties of steel cast in green and in dry sand moulds was made, using steel from a 5-ton acid electric furnace with various complex deoxidizers with and without aluminium. The general conclusion was that, for castings in green sand, the supplementary use of aluminium was necessary.—R. A. R.

Use of Complex Deoxidizers. J. N. Ludwig, jun. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 208–212). The use of complex deoxidizers for acid electric furnace steel castings is discussed with special reference to calcium compounds. Laboratory tests have shown that steel deoxidized with calcium–silicon contains much less oxygen than when deoxidized with 50% ferrosilicon. It is necessary that the preliminary condition and temperature of the metal should be adjusted before the calcium-bearing deoxidizer is added.
R. A. R.

Elementary Principles in Making a Normal-Alloy Electric-Furnace Heat. W. M. Farnsworth. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 226–230). This paper, presented in the educational session of the Conference, describes the melting practice for making chromium–nickel–molybdenum steel in the electric furnace.—R. A. R.

Method for Calculating Electric-Furnace Melting. G. E. Wagner. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 230–232). This short paper explains, with an example, the method of calculating the charge and additions for producing 18/8 stainless steel in a 35-ton electric furnace.
R. A. R.

Determination of Slag Viscosity during the Melting of Steel. V. T. Braga. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1206–1209). [In Russian]. Two simple and reliable viscometers are described which are suitable for measuring the viscosity of slag in the furnace. The first consists essentially of a steel container provided with a long tube which acts as a handle by which the container can be connected for a given time to a large evacuated vessel. Slag is drawn into the container through a graphite capillary tube during the given period and the viscosity is estimated from the weight of the slag. In the second method, the viscosity is calculated from the weight of slag which adheres to a steel disc after touching the slag surface.—S. K.

Main Factors Affecting the Life of Ingot Moulds. B. Körös. (Bányászati és Kohászati Lapok, 1949, vol. 4, July, pp. 296–301; Aug., pp. 329–333). [In Hungarian]. The factors affecting the life of ingot moulds which were investigated were mould design, handling in the steelworks, and the quality of the iron used to make them. Changes in design of some ingot moulds (including the Gathmann type) used in Hungary resulted in a considerable reduction in mould consumption. The influence of mould treatment in the steelworks is discussed and figures of mould life in Hungarian works are given. The quality and composition of the mould material affect the mould life a great deal, first tappings of charcoal pig iron being best. A good composition is: Total C 4·17% (graphitic 3·48%), Si 0·77%, Mn 1·09%, P 0·14%, S 0·04% max. A special pig iron of similar quality to charcoal iron is produced experimentally in Hungary, in a small blast-furnace, from iron containing alumina slag and steel swarf. This iron has the composition: C 4·4%, Si 0·8%, Mn 0·45%, P 0·2%, and S 0·02% for charges composed of bauxite ore 48% and steel swarf 52%. The carbon in a considerable number of consignments was even 5%. The author recommends that the iron obtained from this blast-furnace should be used directly for ingot moulds, without remelting it in a cupola so as to prevent lowering the carbon to 3·4% and increasing the sulphur to 0·08%. The author advocates building a 100-cu. m. blast-furnace for the sole purpose of producing pig for the direct-casting of ingot moulds as this would yield at least 70 tons of pig per day. The steel swarf would be replaced by ingot-mould scrap.
E. G.

Statistical Study of Ingot Moulds. P. Rocquet. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov. pp. 755–757). As a preliminary to a large programme of research on the life of ingot moulds, an examination was made of the distribution of mould life as experienced in a certain works; the only data available were the lives obtained and the compositions of the moulds. The author considers that the absence of data on the conditions of use is the reason why the correlation between mould composition and life is not very apparent, and thinks that this shows that the conditions of use are a more important factor than the composition of the mould.
A. E. C.

Ingot Heat Conservation—Time Studies from Casting to Rolling. A. V. Brancker, J. Stringer, and L. H. W. Savage. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 67–84). Observations have been made at three works of the progress of hot ingots from the casting bay to the cogging mill, in an attempt to find the causes of delays and their effects on soaking-pit operations. The information obtained from these observations and from a study of the routine records of one works has been analysed to find what improvements are possible, especially in reduction of the time during which ingots can lose heat between teeming and charging to the soaking pit. It is concluded that worthwhile savings are possible. In the case of one works it is estimated that feasible improvements, including systematic handling of ingots and a new system of keeping records, could result in an increase in the soaking-pit throughput of 18%, made up of cold ingots. Alternatively, if extra ingots were not available, at least 18% of the pit capacity could be taken out of service whilst maintaining the present throughput.

FOUNDRY PRACTICE

Notes on the Organization and Control of the Production of Castings. Part I. D. Iturrioz. (Metalurgia y Electricidad, 1949, vol. 13, Aug., pp. 22–24). [In Spanish]. The author relates the elements of production control, organization, and progressing of orders in foundries. The difference between planning and 'control of execution' is explained.—R. S.

Casting Design as Influenced by Foundry Practice. O. Smalley. (Institute of British Foundrymen: Foundry Trade Journal, 1949, vol. 87, July 21, pp. 91–95). The author emphasizes the need for closer co-operation between the engineer and foundryman when considering the design of castings. A set of rules is outlined for the designer which would result in sounder castings being produced.—J. C. R.

The Use of Gas in Foundries. A. C. Jennings. (British Cast Iron Research Association: Gas Heat in Industry, 1949, June, pp. 278–282; Aug., pp. 350–356). Brief descriptions are given of rotary and stationary gas-fired sand driers; torches for drying moulds, igniting cupolas, drying-out large and small lades; and batch and continuous annealing furnaces for malleable castings.—R. A. R.

Semi-Mechanised Iron Foundry. (Engineering, 1949, vol. 168, Sept. 2, p. 234). The new foundry of W. H. Dorman and Co., Ltd., Stafford, is described and illustrated. The foundry is in three main sections, namely, green-sand moulding, dry-sand moulding, and the core benches. There are four cupolas with capacities of 2, 4, and 6 tons/hr. as well as a sand reclamation plant. Roller conveyors for moulds and belt conveyors for sand are installed.—R. A. R.

New Memphis Foundry Sets Standard in Good Working Conditions. W. G. Gude. (Foundry, 1949, vol. 77, Sept., pp. 66–71, 152, 155). An illustrated description is presented of the grey iron foundry of the International Harvester Co. at Memphis, Tenn., where various types of farm equipment are produced.—J. C. R.

Modern Cupola Design and Operation at Home and Abroad. W. J. Driscoll. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 21–22). A brief overall picture of modern cupola design and operation, and of recent trends, with special reference to British and American practice is given.—R. A. R.

Water Cooled Cupolas. W. H. Bamford. (British Iron and Steel Research Association, Conference on Cupola and Converter Refractories, May 12–13, 1949, pp. 36–38). A cupola 36 in. in inside dia. operating on charges of 95% steel scrap and 5% ferrosilicon (Si 50%) was fitted with cooling

water tanks with face 30 × 21 in. and 3 in. wide, placed 2 in. apart surrounding the melting zone. Operation was not satisfactory as it was necessary at times to shut off the blast when a 'curtain' of mild steel would form on the faces of the jackets. Later on coolers were fitted to a 30-in. and to two 60-in. dia. cupolas, the former having four tanks requiring a total of 30 gal./min. and the latter eight tanks to each cupola. These tanks are in a rammed lining and have stood up well to two years' service. The tapping temperature is 1450–1500° C., and operation has been very satisfactory.

R. A. R.

Experiments in Nodular Iron. E. K. Smith. (American Foundryman, 1949, vol. 16, Dec., pp. 45–47). Experiments have been performed on the preparation of nodular cast iron by the addition of magnesium to a low-sulphur, low-phosphorus material melted in an acid-lined arc furnace. The magnesium was added, up to 1%, as a 50% magnesium–copper alloy, and early trials gave good physical properties, although the graphite was not fully converted to the nodular form. A second series, where the addition alloy was more carefully sized and stirred in, and the metal skimmed cleaner, produced a structure consisting almost entirely of graphite spheroids and pearlite; the physical properties, except for the elongation were an improvement over the first series, being: yield point 80,000 lb./sq. in., tensile strength 109,180 lb./sq. in., and elongation 2·5%. It was noted that not more than 3·5–10% of the magnesium added entered the iron, and that the treated iron had a greater tendency to shrink than had the untreated. Experiments to produce similar results from cupola-melted iron were unsuccessful owing to the presence of 0·140% of sulphur: magnesium treatment reduced this to 0·05%, but did not produce the nodular structure.—J. P. S.

Spheroidal Graphite Cast Iron. W. W. Braidwood and A. D. Busby. (Foundry Trade Journal, 1949, vol. 87, Sept. 15, pp. 327–334). The treatment of grey cast iron by the addition of magnesium to produce castings containing graphite in spheroidal form is discussed. Particulars are also given of the properties of the treated irons. Both hyper- and hypo-eutectic compositions are suitable for treatment by the magnesium process. The best range of carbon content is 3·2–3·8%, but irons of compositions outside these limits can readily be treated. The fluidity of magnesium-treated irons is similar to that of normal engineering quality grey irons.

R. E.

Economic and Safety Advantages Seen for Improved Nodulizing Alloy. E. T. Myskowski and R. P. Dunphy. (Steel, 1949, vol. 125, Sept. 5, pp. 82–83, 114, 116). **New Graphite Nodulizing Alloy Developed by Naval Research Laboratory.** (Foundry, 1949, vol. 77, Oct., pp. 72–75). **A Graphite Nodulizing Alloy.** (Iron Age, 1949, vol. 164, Sept. 8, pp. 78–79). The carrier evolved for the addition of magnesium to cast iron for 'nodulizing,' by the U.S. Naval Research Laboratory consists of a 50% ferrosilicon containing 8% magnesium. This was originally intended for the deoxidation of cast steel, but has given excellent results in the preparation of nodular cast iron. Inoculation is satisfactory even when 2% aluminium is present in the iron–silicon–magnesium alloy. Nodules are produced in irons containing less than 0·03% sulphur when 0·08–0·10% magnesium is added, provided that 0·06% magnesium remains in the metal and that silicon is above 2·2%; more than 0·04% of sulphur requires a higher magnesium addition, both initially and finally. Examples given show that where sulphur was originally about 0·10%, the addition of about 0·20% magnesium reduced the final sulphur figure to 0·04%, the final magnesium content being 0·07–0·09%, and the graphite in a nodular condition, but it is stated that the condition of the melt has some effect on the amount of magnesium required.—J. P. S.

Electric Furnace Annealing Malleable Iron Castings at the Oliver Corporation. R. C. Cox. (Industrial Heating, 1949, vol. 16, Oct., pp. 1728–1732, 1878). All malleable iron castings are now annealed in electric elevator-type furnaces at the foundry of the Oliver Corporation, South Bend, Ind. Each furnace has a chamber 4 ft. 3 in. wide, 8 ft. 6 in. long and 3 ft. 2 in. high. There are four pairs of furnaces each consisting of one high- and one low-temperature chamber. They are held in frames well above floor level and the castings loaded in trays are placed on cars which travel on rails underneath the furnaces. The car and its load are raised into the furnace, the car bottom sealing the bottom of the chamber. This system saves much floor space. The electricity consumption is 300 kWh./2000 lb. of castings.—R. A. R.

Steel Foundry Practice. A. Stevenson. (Australian Institute of Foundrymen, 1949, Preprint). Recommendations on producing steel castings in a jobbing foundry are made.

R. A. R.

Controls are Stressed by British Steel Foundry. V. Delport. (Foundry, 1949, vol. 77, Oct., pp. 84–89, 168, 170, 172). An illustrated description is presented of steel foundry practice at the works of F. H. Lloyd and Co., Ltd., Wednesbury.

J. C. R.

Steel-Making for Castings. E. C. Pigott. (Metallurgia, 1949, vol. 40, July, pp. 155–158; Aug., pp. 190–193). The following methods of making steel in the steel foundry are described: Basic-Bessemer: acid-Bessemer; Tropenas converter; basic and acid electric furnace processes; electric induction process; rotary furnaces fired with oil, creosote pitch, pulverized coal or gas; and the basic and acid open-hearth furnace processes.

R. A. R.

The Mechanism of Solidification of Horizontal Steel Castings. D. R. F. West. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 182–194). An investigation was made to determine the factors which influence the macrostructures of horizontally cast steel blocks, with special reference to the temperature conditions and rates of solidification. The rates of solidification from the upper and lower surfaces of castings were varied by placing chills of copper and iron on these surfaces, and the resulting macrostructures were examined. Experiments were made to determine the temperature conditions during the solidification of sand and chill castings, by inserting thermocouples into the mould cavity, and measuring the temperatures at intervals after pouring, using a selector switch and a high-speed recorder. The liquidus–solidus ranges of some commercial steels solidifying in the form of castings were investigated, and the temperature gradients and rates of solidification from the upper and lower casting surfaces, for various degrees of superheat, were determined. Rates of solidification were also determined by the pour-out method. The main factor influencing the macrostructure was concluded to be the distribution of centres of crystallization in relation to the rate of solidification. The gravity settling of crystallites was considered to be of particular importance in determining the distribution of these centres.

A Metallurgist Looks at Steel Foundry Operations. E. R. Turner. (Foundry, 1949, vol. 77, Aug., pp. 79, 222–229). Suggestions for improving the efficiency of steel foundry operations are outlined.—J. C. R.

Grinding Problems in the Malleable Iron Foundry. A. S. Rakestraw. (Foundry, 1949, vol. 77, Oct., pp. 95, 184, 186, 188, 190, 192). Three aspects of grinding operations are considered in this article: relationship to foundry costs; the mechanics of grinding; and the application of grinding wheels for specific jobs.—J. C. R.

Causes of Rat-Tail Casting Defects. (American Foundrymen's Society, 1949, Preprint No. 4). This is the final report of an A.F.S. Committee on Physical Properties of Iron Foundry Moulding Materials at Elevated Temperatures (*see* Journ. I. and S.I., 1949, vol. 161, Jan., p. 62). The results of their investigations led to these conclusions: (1) When both hot-compressive strength and confined expansion are high, the sand properties are conducive to formation of rat tails. The rat tail may be alleviated by lowering either of these—in practice it is easier to change hot-compressive strength than confined expansion. (2) Best laboratory tests to determine whether a sand would or would not produce rat tails on castings were hot-compressive strength at 1100° F. and confined expansion test at 1500° F. (3) Addition of moulding sands that confer low hot-compressive strength offers a means of controlling hot strength and yields good results in reducing rat tails when the base sand had a high hot-compressive strength. (4) Increasing the coarseness of sand helps to avoid rat tails as it gives greater latitude in control of mould hardness, hot-compressive strength, and confined expansion. (5) The use of wood flour, cereal, bran, etc. helps to reduce or eliminate rat tails. (6) Moisture content of a sand is not a direct cause but may be an indirect cause of rat tails. (7) Rat tails are most prevalent on the drag side of a test casting. An appendix briefly describes expansion tests on moulding sands with illustrations of the apparatus used.—J. C. R.

Sand in the Mill *vs.* Sand in the Mold. J. B. Caine. (Foundry, 1949, vol. 77, Oct., pp. 68–70, 232–240). The author has studied changes that take place in sand from the time it is mulled or conditioned until the mould is rammed, finished, closed up, and poured. A series of tests is described in which sand specimens have been brought into contact with liquid metal to determine the effect of certain variables on the behaviour of the sand. Some of the factors considered are evaporation during handling, ramming, evaporation after ramming, finishing, and washing. It is suggested that until these variables are controlled, castings cannot be expected to be consistently free from defects.—J. C. R.

Clay as a Binding Medium for Mouding Sand. M. Stap. (Metalen, 1949, vol. 4, Oct., pp. 27–32). [In Dutch]. The properties of clay are discussed and the mechanism of its hygroscopicity is explained.—R. A. R.

Colloidal Clays in the Foundry and in the Refractory Materials Industry. M. Guédras. (Métallurgie, 1949, vol. 81, June, pp. 31, 33, 35).

French Colloidal Clays and Their Application in the Preparation of Synthetic Sands. P. Nicolas. (Fonderie, 1949, Mar., pp. 1510–1520; Apr., pp. 1545–1553). It was desired in France to find a suitable colloidal clay to mix with siliceous sand for the preparation of a synthetic sand for steel casting practice. Tests were carried out on eighteen clays and on American and Italian bentonite for comparison purposes. Results are given of the tests which investigated binding qualities, refractoriness, and physical and chemical properties, and it is considered that French colloidal clays are available which will prove satisfactory for use in synthetic sand preparation.—J. C. R.

Wet System Reclaims Foundry Sand. R. W. Bennett. (American Foundryman, 1949, vol. 15, May, pp. 58–61). An illustrated description is given of the wet sand system for the reclamation of foundry sands.—J. C. R.

Moulding with Very Permeable Cores Having Hardened Surfaces. P. Nicolas. (Fonderie, 1949, May, pp. 1589–1591). Two methods of obtaining cores possessing high permeability and great surface strength are described, one using sand containing cement and the other sand containing sodium silicate.—J. C. R.

The Behaviour of Moulding Sand when Casting Steel. H. Zeuner and K. Roesch. (Neue Giesserei, 1949, vol. 36, July, pp. 195–199). Measurements of the changes in the length and the permeability of moulding sands were made with a view to determining the causes of scab formation on steel castings. The temperatures of the β-quartz $\rightleftharpoons$ α-quartz transformations on heating and cooling, and the changes in length remained practically the same whatever the rates of heating and cooling. The gas permeability fell rapidly with increasing temperature up to about 450° C. and then remained constant in the case of the German sands tested. The quantity of gas evolved at the face of a mould when the steel is poured rises very rapidly in the first 10 sec., it then falls fairly rapidly over the next 30 sec. or so; this is followed by a smaller rise and a final but quite gradual fall. In general, scab formation, on steel castings can be prevented by (*a*) using coarse sand with little clay and moisture, and organic binders, and (*b*) careful ramming, pouring at a uniform rate, and, when casting flat plates, inclining the mould at about 20°.—R. A. R.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Control and Inspection of Heat-Treated Parts. H. E. Boyer. (Steel Processing, 1949, vol. 35, Aug., pp. 418–423; Oct., pp. 537–541, 562). The relative importance of testing at various stages in the manufacture of heat-treated steel parts is pointed out, temperature control equipment and its maintenance are described, and brief outlines of magnetic methods of testing are given.—R. A. R.

Estimation of the Tendency to Deformation of a Steel during Its Heat-Treatment. R. I. Mochalkin. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1229–1232). [In Russian]. In the method described for estimating the tendency to deformation of steel parts when undergoing heat-treatment, changes in the lengths of cylindrical specimens, 20 mm. in dia. and 100 mm. long, which took place on quenching and tempering at 640–660° C. were noted and the residual deformations calculated. Results obtained for carbon steels quenched in water showed residual deformations of $-0{\cdot}27$ to $+0{\cdot}28\%$, whilst the corresponding values for alloyed steels were $+0{\cdot}14$ to $+0{\cdot}32\%$ for quenching in water and $-0{\cdot}09$ to $+0{\cdot}10\%$ for oil-quenching. Possible improvements and extensions of the use of this method are considered.—S. K.

Some Aspects of Salt Bath Furnaces Discussed in Their Application to the Wire Industry. B. M. Pearson. (Wire Industry, 1949, vol. 16, Oct., pp. 811–813; Nov., pp. 889–893; Dec., pp. 973–975). The advantages of the immersed-electrode salt bath for annealing, spheroidizing, and patenting wire are pointed out in Part I. Furnaces of this type and their equipment and operation for treating coils of wire are described in Part II. The substitution of the salt bath for the lead bath for patenting wire is referred to in Part III; the former process is gaining ground. A salt-bath installation at the Borg-Warner Corporation of America is described. It has a steel pot 5 ft. × 4 ft. 9 in. × 5 ft. deep which is thoroughly insulated; an insulated cover mounted on flanged wheels runs on a steel track. The pot is charged with 13,000 lb. of a 50/50 mixture of sodium carbonate and potassium chloride. Charges of 1000 lb. consisting of eight coils of wire are immersed in the salt for 30–40 min. The salt is at 1280° F. and the work is cooled in air to below 700° F., and then plunged in water to remove the salt. Power consumption is 195 kWh./ton and the labour assigned to the job is one man.

R. A. R.

Dry Cyaniding Reduces Costs on Variety of Steel Parts. F. R. Nethaway. (Materials and Methods, 1949, vol. 30, Sept., pp. 61–63). The advantages obtained by gaseous nitriding of small parts as compared with molten cyanide baths are pointed out and the equipment for the former process is briefly described.—R. A. R.

Deep Case Gas Carburizing of Nash Gears. (Industrial Heating, 1949, vol. 16, Oct., pp. 1714–1724, 1883–1886). A large gas-carburizing installation for differential and other gears at the works of Nash-Kelvinator Corp., Kenosha, Wis., is described and illustrated. The furnace is 44 ft. long with an inside width of 6 ft. 3 in. The work is loaded in trays which are pushed through the furnace in four rows with separately controlled rates of movement to give different case depths. The normal time for passing through the furnace is about 8 hr. The carburizing atmosphere consists of cracked propane with a dew-point of $-10°$ F. with the composition CO 23–25%, H_2 35–36%, CH_4 0·5% max., balance nitrogen and raw propane in the proportions of 1250 to 50 cu. ft./hr. The case on the gears is 0·040 to 0·045 in. deep with a hardness of Rockwell C62.—R. A. R.

Apparatus for the Control of the Process of Gaseous Cementation. A. I. Glazova. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1249–1252). [In Russian]. The design is given of a gas-analysis apparatus which can be used to determine hydrogen, saturated and unsaturated hydrocarbons, carbon monoxide and dioxide, oxygen, and nitrogen in gas mixtures occurring in gaseous cementation; it is also suitable for the analysis of coke-oven gas, producer gas, and town gas. The apparatus includes nine special absorbing vessels with a manifold and taps for interconnecting them, a combustion furnace, aspirators, and a gas burette, the whole being mounted on a special stand.—S. K.

Large-Scale Production Carburizing. (Steel, 1949, vol. 125, Sept. 19, pp. 64–65). The Warner Gear Division of the Borg-Warner Corp., Muncie, Ind., uses seven continuous gas-fired radiant-tube automatic atmosphere furnaces, each heat-treating 800–1000 lb. of parts per hour. An atmosphere of 20% carbon monoxide, 40% hydrogen, and 40% nitrogen, enriched by natural gas, is employed.—J. P. S.

Continuous Gas Carburizing. R. J. Cowan. (Steel, 1949, vol. 125, Sept. 5, pp. 78–81, 127; Sept. 12, pp. 114–116, 118, 120). Continuous gas carburizing is described from its origins to the present day, and explanations of early failures and unexpected phenomena are given. The process consists of passing the work to be carburized through a muffle furnace along with a hydrocarbon gas diluted with carbon dioxide, a little carbon monoxide, and some nitrogen. The cooler zone at the feeding end of the muffle causes the deposition of carbon on the work in the form of soot, and in the higher-temperature, or active carburizing, zone next entered, carburizing reactions take place as follows: $C + CO_2 = 2CO$ and $3Fe + 2CO = Fe_3C + CO_2$. Where natural gas is used for carburizing, the diluent gas may be flue gas from the combustion of fuel gas, but where propane and butane are used, these break down at low temperatures, producing

unsaturated hydrocarbons. These react among themselves to produce a sort of liquid tar, which finally emerges as a 'carbon scale' on the work underneath which there is little carburization. The diluent used in these circumstances is known as 'CG gas' produced by the reaction under heat of a mixture of hydrocarbon gases and air in non-combustible proportions; a mixture of hydrogen (30%) and carbon monoxide (20%) is produced. The pressure of this hydrogen prevents the deposition of tar. The author also deals with the use of oil as the source of hydrocarbons for the continuous carburization process and describes the 'Pyrol' plant developed in conjunction with Russian engineers. Here, kerosene oil is cracked at low temperatures to produce a gas rich in unsaturated hydrocarbons which is used as the carburizing gas; it is diluted with a gas made by washing a portion of this rich gas with water and oil, and then reacting it with steam at a higher temperature, this product being rich in hydrogen and carbon monoxide. Though 40 units were supplied to Russia, the process has never been exploited in America.—J. P. S.

Carburizing-Martempering Procedure Streamlines Crankshaft Heat Treatment. J. J. Ebner. (Steel, 1949, vol. 125, Oct. 3, pp. 72–74, 94). A combined installation for carburizing and martempering is described; salt baths are used throughout, one at 1760° F. (960° C.) for carburizing, a stabilizing neutral wash bath at 1450° F. (790° C.), an isothermal quench bath at 400° F. (200° C.), and a tempering bath at 450° F. (230° C.). The parts in question are outboard motor crankshafts; they are carburized all over, the threads at one end being subsequently ground in.—J. P. S.

High-Frequency Heating. R. de Lucas Ortueta and J. M. Herrero Botas. (Anales de Mecanica y Electricidad, 1949, vol. 25, July–Aug., pp. 207–219). [In Spanish]. This article surveys the possibilities of using this new technique, including the application of small potentials. Some short theoretical considerations serve as a basis for an approximate calculation which permits rapid estimation of the possible applications for any given process.—R. S.

Stress Relieving Steel Springs in Recirculating Ovens at Plant of Universal Wire Spring Company. (Industrial Heating, 1949, vol. 16, Sept., pp. 1532–1536). An illustrated description is given of an installation of four stress-relieving ovens for leaf springs at the works of the Universal Spring Co., Cleveland, Ohio. Each oven has inside dimensions of 10 ft. 4 in. × 5 ft. 2 in. × 6 ft. 4 in. high. Heat is supplied by a single dual-purpose burner taking either oil or gas. The hot gases are circulated by a blower. The stress-relieving temperature of 400–550° F. is reached in about 8 min. and the charge is held at this temperature for about 30 min. The springs are given this treatment twice in the course of cold-working operations.—R. A. R.

Induction Annealing Simplifies Metal Forming. L. R. Mueller. (Iron Age, 1949, vol. 164, Sept. 1, pp. 69–71). Local induction heating of sheet metal in hard tempers enables many operations to be performed which would otherwise be impossible.—J. P. S.

Gas Fired Annealing Furnace Handles Railroad Tank Cars. (Iron Age, 1949, vol. 164, Sept. 8, pp. 85–86). A large car-type gas-fired annealing furnace has been constructed by Jet Combustion, Inc. of Chicago, for the Pressure Welding Division of the General American Transportation Corporation. It is 52 ft. long inside with a width of 19 ft. and a height of 21 ft. clear. A vessel 16 ft. in dia. 50 ft. long can be accommodated; the furnace plus a load of 75 tons weight can be brought up to 1600° F. (870° C.) in 3 hr.—J. P. S.

Bearing Balls Hardened within Close Limits in Automatic Shaker-Hearth Furnace. J. H. Bradley. (Industrial Heating, 1949, vol. 16, Oct., pp. 1734–1736, 1881). An electric furnace for hardening bearing balls from $\frac{1}{16}$ to $\frac{1}{2}$ in. in dia. at the rate of 150 lb./hr. is described. The hearth consists of a steel plate which is moved forward slowly by a cam every 10 to 30 sec., depending on the size of balls, and then jerked back by a spring to the starting position, leaving the balls one step forward on the hearth.—R. A. R.

Diagram for Determining the Hardenability of Steel from the Critical Cooling Velocity of Quenching. I. F. Afonskii. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1074–1077). [In Russian]. Data from the literature are examined and used for the construction of a diagram of critical cooling velocity against critical diameter for quenching in water, in oil, and in air. The following information can be obtained from this diagram: (*a*) The cooling velocity of the centre of a solid cylinder; (*b*) the critical diameter of a cylinder for complete hardening, knowing the critical cooling velocity of the steel; and (*c*) the value of the critical cooling velocity which a steel must possess for hardening to a given depth. The application of this diagram for technical processes is described and exemplified.—S. K.

Method of Determining the Critical Cooling Velocity of Quenching. M. E. Blanter. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1077–1079). [In Russian]. Using hardenability specimens of various steels, the relationship between the martensitic and semi-martensitic zones, and between the upper critical cooling velocity and the latter zone are considered. With the results as a basis, the influence of the elements manganese, phosphorus, sulphur, silicon, nickel, chromium, and molybdenum on the upper critical cooling velocity is studied. The greatest influence was found to be exerted by molybdenum, which lowered the critical cooling velocity from 150 to 4·2° C./sec. when its content was increased from 0·01 to 0·74% in a steel containing 0·4% of carbon, 0·6% of manganese, and 3·5% of nickel.—S. K.

Heat Treatment of Tool Steels by Martempering. R. P. Seelig. [Iron Age, 1949, vol. 164, Sept. 1, pp. 72–76). In the study of the heat-treatment of high-carbon, high-chromium steels it has been ascertained that: (1) It is necessary to hold the material at the quenching temperature for about half an hour to obtain full hardness; (2) heating directly to the austenitizing temperature does not lead to cracking or distortion; (3) martempering gave a lower expansion than oil-quenching, with a slightly lower hardness, although air-quenching gave less expansion still, with greater loss of hardness; and (4) sub-cooling caused further transformation of austenite with slight expansion and a small increase in hardness.—J. P. S.

FORGING, STAMPING, DRAWING, AND PRESSING

Pittsburgh Forgings Company—A Study in Progress. J. C. McComb. (Steel Processing, 1949, vol. 35, Sept., pp. 474–490). A comprehensive account with many illustrations is given of the activities of the Pittsburgh Forgings Company. The equipment in the forging shops includes 14 steam hammers, 13 board hammers, 3 helve hammers, and 4 upsetters. About 4500 tons of steel are sheared per month for forgings. The greater part of the production is for agricultural machinery.

Die Sinking for Drop Forging. Part V—Die Sinking. J. Mueller. (Steel Processing, 1949, vol. 35, Oct., pp. 542, 543, 564, 565). Continuation of a series of articles (*see* Journ I. and S.I., 1950, vol. 164, Mar., p. 366). A description is given of the die-sinking operations in making a pair of dies for forging steel towing hooks.—R. A. R.

New Developments in the Cold Forming of Steel and Light Metals. (Metallwirtschaft, 1949, vol. 3, Sept., pp. 301–303). Brief outlines are given of the processes of cold pressing and deep-drawing steel and light metals.—R. A. R.

Tungsten Carbide Tooling for Cold Heading. W. E. Montgomery, W. Leigh, and W. H. Phillips. (Steel Processing, 1949, vol. 35, Aug., pp. 407–412; Oct., pp. 531–536, 563). Factors affecting the design of tungsten carbide dies for cold heading and extrusion in the manufacture of bolts are discussed. Many of the operations are described in detail and dimensions of dies for several sizes of bolts and screws are given.—R. A. R.

Back Pull Wire Drawing. D. Lewis and H. J. Godfrey. (Wire and Wire Products, 1949, vol. 24, Oct., pp. 873–885, 982, 983). A five-die back-pull wire-drawing machine with instruments showing the die pressure at each die, block pull in pounds at each block, finishing speed, and armature current, is described and results obtained with it are presented and discussed. A special device was incorporated to measure the surface temperature of the moving wire. The application of back pull resulted in: (1) Less pressure between the wire and die; (2) longer die life; (3) lower power requirements; (4) reduced temperature of the wire surface; (5) more forward pull being required; and (6) less reduction in area on fracture of the wire in a subsequent tensile test. In general, there seemed to be no great practical advantage in using back-pull drawing for low-carbon steel wire.—R. A. R.

Planning for Wire Mill Handling. F. L. Hayden. (Wire and Wire Products, 1949, vol. 24, Oct., pp. 935–936). Suggestions are made for improving the means of transporting material in a wire mill.—R. A. R.

Possibilities in Handling Wire and Wire Products. J. W. Galloway. (Wire and Wire Products, 1949, vol. 24, Oct., pp. 938–940, 966). Methods of improving the handling of coils in a wire mill are suggested. In one small mill one man in the cleaning shop can receive coils one at a time and weld the ends together to form 3000-lb. coils which are dealt with by an overhead crane.—R. A. R.

Diagrammatic Calculation of Die Sizes. E. L. Baay. (Wire Industry, 1949, vol. 16, Sept., pp. 735–738). Diagrams are presented for the easy and rapid calculation of the bore sizes on multiple wire-drawing machines.—R. A. R.

A Wire-Drawing Die Profilometer. R. M. J. Withers. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 63–66). The paper describes the development of an instrument designed to measure and reproduce the profiles of the bore of wire-drawing dies. It is intended for use with die bores with throat diameters in the range of 0·02 to 0·25 in. It can be used to measure accurately the bore diameter. The limit of measurement is 0·0001 in.

ROLLING-MILL PRACTICE

Giant New Plant at Midland Has United Hot and Cold Rolling Mills. (United Effort, 1949, vol. 29, Sept.–Oct., pp. 3–5). New rolling-mill plant at Midland Works of the Crucible Steel Company of America is briefly described. A four-high hot-finishing stand for strip in widths up to 62 in. has work rolls 27 in. in dia. with back-up rolls 48 in. in dia. with 66 in. face, and two coilers are housed in removable gas-fired furnaces, one on each side of the stand. In the tandem cold-rolling mill the first stand is a four-high unit with work and back-up rolls of 16½ in. and 53 in. in dia. respectively.—R. A. R.

Electrical Equipment Used in Cold Rolling of Thin Steel Sheets. M. J. Delastre. (Bulletin de la Société Française des Electriciens, 1949, vol. 9, Mar., pp. 138–147: Electrical Engineering Abstracts, 1949, vol. 52, Aug., p. 312). The equipment is automatic, reduces steel sheets 3–5 mm. in thickness down to 0·8–0·2 mm., in six to ten passes, is powered on the Ward-Leonard system by motors of 350 h.p., and is controlled by auxiliary fields on the exciter of the Ward-Leonard generator. Reasons for the adoption of this method of control are given, and comparisons are made with other methods.

Rolling Mill Drive with Speed Regulation by Means of a Rectifier Cascade. F. I. Butaev and N. B. Jacobson. (Vestnik Elektropromyshlennosti, 1948, vol. 19, Nov., pp. 11–16 [in Russian]: Electrical Engineering Abstracts, 1949, vol. 52, Aug., p. 312). The method, introduced in 1948, employs inverter-fed mercury-arc rectifiers; the speed regulation is achieved by controlling the phase of the ignition of a group of rectifiers.

Rotary Gang Slitting. E. L. Mackey. (Steel, 1949, vol. 125, Sept. 26, pp. 66–70, 88, 90; Oct. 3, pp. 75–78, 80; Oct. 17, pp. 77–80, 84). Gang slitters, working on the pull principle, are described, together with the necessary recoilers. The advantages of slitting wide strip for the production of narrow strips are discussed.—J. P. S.

LUBRICANTS AND LUBRICATION

Prescribed Lubrication for Iron and Steelmaking Equipment. A. F. Brewer. (Steel, 1949, vol. 125, Sept. 12, pp. 106–109, 146). Applications of centralized automatic lubrication in coal-handling equipment, turbo-blowers, blast-furnace charging gear, open-hearth chargers, ladle cranes, and electric furnace tilting gear, are described.—J. P. S.

Experience Gained in the Use of Viscometers. V. N. Bratchikov. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., p. 1257). [In Russian]. A more robust viscometer for use with lubricating and other oils is proposed in the light of experience gained under industrial conditions.—S. K.

WELDING AND FLAME-CUTTING

Some Aspects of Welding Research in Great Britain and America. H. G. Taylor. (Transactions of the Institute of Welding, 1948, vol. 11, Dec., pp. 206–211). In the first part of this paper, the author, the Director of Research of the British Welding Research Association, deals with welding research in Great Britain, especially that carried out by B.W.R.A., on the engineering side at Cambridge and Abington Hall, and on the metallurgical in London. The work on welded structures, on residual stresses, on welded pressure vessels and pipe bends is described, together with the recommended codes of practice, such as for the spot-welding of mild-steel sheet and for the radiographing of welded joints in mild-steel pressure vessels which the Association has been able to formulate. The needs of the Association in financial support and in equipment, are described.—J. P. S.

Strain Aging in Welding Structural Steel. W. H. Bruckner and S. W. Sandberg. (Welding Journal, 1949, vol. 28, Sept., pp. 397-s–404-s). The effects of strain-ageing on rimmed steel, as rolled, have been examined by the method employed by the first author and W. E. Ellis in the case of semi-killed steel (*see* Journ. I. and S.I., 1949, vol. 161, Mar., p. 263). This involves the production of a strain gradient by the drawing down of a tapered specimen to a cylindrical shape; hardness variations with time and temperature were studied at various strain levels, and Charpy **V**-notch impact tests were employed to determine notch sensitivity and transition temperatures. E6010 electrodes were employed, and all-weld-metal specimens were studied as well as specimens of the base metal. Indications of strain-ageing were found in the base metal after plastic strains as low as 0·5% elongation, though for the weld metal there was no such indication below 2% plastic strain. The weld metal was sensitive to quench-ageing. The transition temperature for the rimmed steel, depending on the method of stress relief, varied between 75° and 95° F. (24° and 35° C.) that of the weld metal between − 15° and 20° F. (− 26° and − 7° C.); the use of mechanical stress relief, *i.e.*, plastic strain up to 0·25% elongation, is considered to have advantages over thermal stress relief in lowering the transition temperature of both materials.—J. P. S.

Instrumentation for the Evaluation of the Stability of the Welding Arc. L. P. Winsor, L. McDonald Schetky, and R. A. Wyant. (Transactions of the American Institute of Electrical Engineers, 1949, vol. 68, Part I, pp. 525–533). This paper is in the nature of a progress report describing instruments developed to date at the Rensselaer Polytechnic Institute for measuring the characteristics of the welding arc which influence its stability.—R. A. R.

Operating Characteristics of Arc Welding Electrodes. F. W. Myers. (Steel, 1949, vol. 125, Sept. 19, pp. 79–82, 84). Factors involved in the deposition of weld metal include the correct manipulation of the electrode, control of the slag and of the length of arc, and the proper choice of polarity. The microstructure of the deposit is also affected by electrode composition, base metal composition, and weld shape. Weld penetration, the depth of the heat-affected zone, and the rate of deposition give useful indications of the suitability of electrodes for various purposes.—J. P. S.

Electrodes Containing Rutile. R. D. Van Zante, T. R. Graham, and R. G. Knickerbocker. (Welding Journal, 1949, vol. 28, Sept., pp. 438-s–444-s). Electrodes coated with compositions containing rutile (a mineral containing titania) obtained from the Arkansas deposits, have been tested against similar electrodes coated with compositions containing commercial rutile, the basis of tests being the tensile properties of an all-weld-metal specimen. Electrodes containing commercial rutile meet the requirements of the American Welding Society–American Society for Testing Materials Standards, but those containing Arkansas rutile do not do so in every case. This is in part due to the sulphur contained in the latter rutile, but owing to the presence of other impurities and uncertainty about their influence on slag characteristics and so on, the controlling factor cannot yet be said to have been isolated.—J. P. S.

Coated Electrodes. J. Němec. (Svařování, 1949, vol. 9, Sept., pp. 119–126). [In Czech]. The paper deals with the effect of the coating and with the requirements to be met by electrodes; there is guidance on the selection of electrodes suitable for a given purpose. Both neutral and lime-coated electrodes are dealt with. Data on the nitrogen content, and notch toughness of the weld metal obtained, and on the mechanical properties of welds made with a wide variety of electrodes of Czech manufacture are given.—E. G.

The Influence of Core Wire on the Characteristics of Low Carbon Steel Welding Electrodes. C. B. Voldrich, D. C. Martin, and P. J. Rieppel. (Yearbook of the American Iron and Steel Institute, 1949, pp. 397–468). Welding electrodes were made of wire made from steel taken from different locations in ingots of rimming, semi-killed, and killed steel, and coated with one of three types of coating material. The semi-killed and killed steel cores did not make good electrodes

when covered with E6012 coating. The most important single variable affecting the operating characteristics of the covered electrodes was the sulphur content of the wire. The position in the ingot from which the wire came had no discernible significance, whereas the type of coating had an important effect.—R. A. R.

Production of Butt and Lap Welded Pipe Conduit and Electric Metallic Tubing. H. E. Engelbaugh. (Steel, 1949, vol. 125, Sept. 5, pp. 92–109). The author describes the early history of pipe-making from the Babylonian use of clay pipe, to the use by Murdock, the inventor of gas lighting, of surplus gun barrels. The introduction of a die, or bell, for forming butt-welded pipe from strip is due to Cornelius Whitehouse in 1825, and the development of modern roller methods to Moon and Fretz, whose first patents were issued in 1923. The manufacture of lap-welded pipe is described ; the heated skelp is drawn through a die to overlap, but not weld, the edges, and, after reheating, passed between a bullet-shaped mandrel and a pair of rolls which weld the lap and reduce it to the thickness of the rest of the wall of the pipe. Butt-welded pipe is still made by pulling the skelp through a die, and continuous welded pipe from coils of strip up to 500 ft. in length by the Fretz-Moon process, being cut off in lengths as required. The author next traces the development of electric cable conduit from its beginnings as paper tube, via brass- or steel-covered paper to the thin-walled enamel-coated steel tube in use today : this is made from electrically welded strip. Mechanical tubing, which has many engineering uses, is made from cold-rolled strip welded by electric-resistance or gas welding.—J. P. S.

Fatigue Tests of Spot-Welded Steel Sheets. G. Welter. (Welding Journal, 1949, vol. 28, Sept., pp. 414-s–438-s). An elaborate investigation of the fatigue strength of mild steel and stainless steel spot welds, made under pulsating tension has shown the following results, among others : (1) Fracture under pull-pull tests begins by a crack invariably placed adjacent to the top of the spot, in the longitudinal axis of the specimen and spreading on both sides of it. (2) A considerable increase in fatigue strength is obtained by applying loads of up to 400,000 lb./sq. in. to the faces of the welded spot during testing. (3) The guiding of the specimen to prevent binding during the test increases the proportional limit of the joint as well as the maximum load by 40–50%. (4) Combined stresses reduce the fatigue limit. (5) An increase in the moment of inertia of the spot in the plane of bending, such as might be produced by welding a ring instead of a spot, would raise the endurance limit of the joint.—J. P. S.

Spot Welding Galvanised Steel. H. L. Begeman, M. L. Hipple, and L. Cullum, jun. (Welding Journal, 1949, vol. 28, Sept., pp. 385-s–395-s). Experiments have been carried out on the spot welding of hot-dipped galvanized steel. Optimum conditions are found to depend on the coating thickness to some extent, the welding current rising with the thickness when electrode pressure and weld period are constant. The strength of the weld is found to increase with an increase of welding current, and to increase to a maximum which remains constant, with increased weld period ; at low welding currents, weld strength decreases with increased electrode pressure, though high currents and variations of electrode pressure affect weld strength but little. The metallurgical structure of the weld nugget appears dendritic ; the zinc at the internal faces of the weld is apparently expelled during the process. Further experiments were carried out to examine the effect of cooling the electrode tips to 0° F. (— 18° C.) ; here it is concluded that optimum welding conditions do not depend greatly on cooling temperature, and that departures from optimum conditions obscure the benefits of cooling. The greatest benefit is in the extension of electrode tip life, but this may be outweighed by the additional complications introduced.—J. P. S.

Welding Dissimilar Metals. (Steel, 1949, vol. 125, Sept. 26, pp. 72–74, 76). The successful resistance welding of dissimilar metals, such as brass to stainless steel, or copper to Nichrome may be assisted by choice of electrodes so that a low-resistance electrode helps to conduct heat from the high-resistance material, and a high-resistance electrode helps to intensify the heat in the low-resistance material. To weld copper to aluminium requires a low electrode pressure till the correct temperature is reached, and then a high pressure to extrude most of the copper–aluminium compound from the weld. Where heat-resisting alloys have to be welded together, the interposition of a third material such as nickel or a nickel alloy, will assist welding.—J. P. S.

Welding in the Wire Industry. J. H. Corson. (Wire and Wire Products, 1949, vol. 24, Oct., pp. 866–872, 984–989). Two methods of welding high-carbon steel wire are described. These were developed in an attempt to produce a joint which, after drawing the wire, would pass the wrapping test. The resistance welding and the pressure welding below fusion temperature did not produce joints which would pass the wrapping test. A brief description is also given of an automatic welding and annealing machine for producing annealed welds in wire rope wires.—R. A. R.

Electric Welding and Cutting under Water in the Soviet Union. K. K. Chrenov. (Svařovàni, 1949, vol. 9, Aug., pp. 110–112 ; Sept., pp. 129–131). [In Czech]. The author has developed methods of electric welding under water on the basis of experiments carried out in 1942–43. Standard-type 5-mm. electrode wire with carbon up to 0·18% is used. The coating is usually made of finely ground mineral substances mixed with waterglass and dried at 200–300° C. to remove moisture entirely and to increase mechanical strength. The coating is required to develop a crater and to generate gases with a low ionization potential. It is possible to produce under water the same types of weld as are usual in air. The widths of the weld and the transition zones are smaller than in welds made in air because of the greater cooling effect of the water. The weld has a fine grain structure and has more non-metallic inclusions than welds made in air. The quality of welds is satisfactory and in rupture tests a tensile strength of 35·1 to 37·7 kg./sq. mm. was measured ; it was generally the base metal which broke. Visibility is usually very poor, but experienced welders can work by touch even when the water becomes entirely non-transparent as a result of the cloud of ferrous oxide which is generated during welding. The work is difficult because a diver easily loses his balance and his clothing is unsuitable for carrying out work demanding carefully controlled movement of the hands. Under-water welding has been used for repairing cracks and pipes and building up worn material. The distortion when welding under water is very small. Under-water cutting with an electric arc requires currents of 1000 amp. or more, and a very thick electrode coating. The arc voltage is 40–50. The intense heat concentration causes a considerable amount of gas to be generated and this helps to remove the metal from the cut. In 1942, 432 sections of an ice-breaking structure of a bridge were cut under water in 40 six-hour shifts. The total length cut was 137 m. The cutting speed was about five times as high as when using an oxy-hydrogen flame. Cutting by electric arc is competitive with any other methods for thicknesses up to 15 mm. Experiments were also carried out with cutting by electric arc and an oxygen stream. A current of 300 amp. is required and the oxygen consumption is one-third to one-quarter of that for cutting with an oxy-hydrogen flame. Difficulties are encountered with the electrodes as these burn away very rapidly. Experiments with liquid fuels for cutting were also successful and a burner is at present being developed for under-water cutting with petrol atomized by an oxygen stream.—E. G.

MACHINING AND MACHINABILITY

Cutting Stainless by Friction Band Sawing. H. J. Chamberland. (Iron Age, 1949, vol. 164, Sept. 1, pp. 77–79). The cutting of sheet and plate, and the gates and risers from castings, with the friction band-saw is described. Velocities of 5000–14,000 ft./min. are described ; at the latter velocity, plate 1 in. in thickness can be cut at 12·8 in./min.—J. P. S.

The Importance of Superfinish—Development and Present Position of the Process. H. Opitz and K. Krümmel. (Zeitschrift des Vereines deutscher Ingenieure, 1949, vol. 91, Sept. 1, pp. 417–424). The superfinish grinding process, the equipment, and surface-roughness measuring are described and some German investigations of the process are reported. Particles extracted from used grinding oil were found, under high magnification, to consist of entangled 'turnings,' spirals, and minute crystallites. The process is therefore a combination of turning and grinding and it can also be regarded as an artificial form of running-in. Extra-hard stones in the grinding face remove little of the surface roughness as they become glazed and cease to cut. Stones which are too soft remove the initial surface roughness of the work and then frequently create a new roughness greater than

before. For work of a given hardness there is a certain stone hardness which produces the minimum roughness. With increasing hardness of the work the stone hardness to produce this minimum decreases.—R. A. R.

The Manufacture of Standard Samples for Surface Finish. M. Mayer. (Revue Générale de Mécanique, 1949, vol. 33, Aug., pp. 316–318). The manufacture of plastic replicas of standard samples of surface roughness is described : these are intended for workshop use. The human finger-tip is used in comparing the surfaces of machined parts with these standards and it is claimed that normal sensitivity lies between 0·1 and 1·0 micron.—R. F. F.

A Mechanical Profiling Device. F. A. Abramov and A. F. Miletich. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1138–1139). [In Russian]. A simple and robust device for measuring the surface roughness of both metallic and relatively soft surfaces is described.—S. K.

The Electro-Fragmentation Process. D. W. Rudorff. (Engineers' Digest, 1949, vol. 10, Sept., pp. 306–308). The author reviews earlier investigations of the mechanism by which electric arcs and spark discharges break up metals, and explains the conditions necessary for applying electric sparks to the machining of metals.—R. A. R.

CLEANING AND PICKLING

Simplified Methods of Cleaning Metals for Plating. J. L. Bleiweis. (Materials and Methods, 1949, vol. 30, Sept., pp. 74–77). Methods of cleaning ferrous and non-ferrous metal parts before plating are briefly reviewed. Preliminary methods include applying a chlorinated solvent by vapour, immersion, or spray ; sprayed petroleum spirits ; spraying or immersion in an emulsion cleaner ; spraying or immersion in an alkaline cleaner. The cleaning of nickel-plated parts before plating with another metal is discussed.—R. A. R.

Pickling Acid Measurement and Control. D. H. Krouse. (Blast Furnace and Steel Plant, 1949, vol. 37, Aug., pp. 961–964). The applications of the 'Flowrator,' a flowmeter constructed of non-corrodible alloys such as Monel or Hastelloy 'C,' to the control of pickling solutions is described. Manual and automatic systems for maintaining acid content, using this type of flowmeter are illustrated.—J. P. S.

Methods of Chemical Control in the Preparation of the Surface of Steel Wire. I. I. Vainshenker and Z. I. Granik. (Zavodskaya Laboratoriya, 1949, vol. 15, Aug., pp. 1006–1007). [In Russian]. The determinations of the concentrations of acid, ferrous sulphate, copper sulphate, and calcium oxide in solutions used for preparing the surface of steel wire are described.—S. K.

Descaling Wire. (Wire Industry, 1949, vol. 16, Nov., pp. 905–906). A process for removing scale, rust, and cement from iron and steel is described. It consists of dipping the article or material in a solution of Jenolite, a colourless and odourless liquid with a specific gravity of 1·28. It is claimed that a phosphate deposit is left which protects the metal surface from re-rusting for a considerable time.—R. A. R.

Processing of Stainless Steel Wire. S. P. Watkins. (Wire and Wire Products, 1949, vol. 24, Oct., pp. 916–923, 968–972). The cleaning, pickling, drawing, and annealing of stainless-steel wire are described. For pickling, most producers use an acid method consisting of a sulphuric acid bath (5–10%) plus an inhibitor (1–2%) at a temperature of 140° F., followed by a nitric acid (3–5%) with hydrofluoric acid (0·5–1%) bath at room temperature. It is common practice to coat the wire with lead before drawing and to make the first drafts heavy, *e.g.*, to reduce 17% chromium and 18/8 stainless steels from $\frac{1}{4}$ in. to 0·110 in. in six drafts. Carbide dies with an approach angle of 12° to 16° and 30° back relief are used. R. A. R.

Some Aspects of Pickling and Pickle Recovery. N. Swindin. (Iron and Coal Trades Review, 1949, vol. 159, Oct. 21, pp. 941–944). Using the ternary system $FeSO_4$–H_2SO_4–H_2O the author describes three ways of returning free acid to the bath and recovering iron sulphate from waste pickle liquor. A brief account of the pickling of stainless steel is given : tanks lined with new carbon materials, Karbate, Morganite, and Delanium are used for this purpose.—J. C. R.

Report of the Water Pollution Research Board with the Report of the Director of Water Pollution Research. (Department of Scientific and Industrial Research, 1949, pp. 39–48 : H.M. Stationery Office). In the section on the treatment of waste washing water from a continous pickler, experiments are described which showed that addition of strongly alkaline reagents which caused immediate precipitation of dissolved iron gave precipitates which were more bulky and difficult to handle, whereas dense and readily filterable precipitates were produced under conditions which favoured gradual precipitation.

A study of the reaction of chlorine with cyanide was also made to determine the best conditions for using the process to treat electroplating wastes.—R. A. R.

Electrolytic Pickling for Galvanizing and Terne Lines. E. A. Matteson. (Products Finishing, 1949, vol. 13, July, pp. 42–46). Two electrolytic pickling installations at the works of the Carnegie-Illinois Steel Corporation are briefly described. In these, anodes and cathodes are placed alternately above and below the strip, and glass guides prevent the strip touching them. In one case the bath contains 20% H_2SO_4 at a temperature of 160–180° F., and the acid consumption has been 60 lb./ton of sheets.—R. A. R.

On the Explosion Dangers of Aceto-Perchloric Electrolytic Polishing Baths. L. Médard, P. A. Jacquet, and R. Sartorius. (Société Française de Métallurgie, Oct. 21, 1948 : Revue de Métallurgie, Mémoires, 1949, vol. 46, Aug., pp. 549–560). The characteristics of perchloric acid and aceto-perchloric polishing baths are discussed, brief details of some accidents during the use of such baths are given, the explosive properties of aceto-perchloric mixtures are described, sensitivity to detonation is referred to, and experiments to determine the properties of the "complete combustion" mixture (68 parts by volume of perchloric acid of density 1·59, and 32 parts by volume of acetic anhydride) and explosion tests by inflammation and by heating are described. A triangular composition diagram (perchloric-acid/acetic-anhydride/water) shows which mixtures are inflammable, which are liable to detonation, and which are safe in use. The most explosive mixture is that mentioned above. Mixtures with less than 55% of perchloric acid by volume and those made with acetic anhydride and perchloric acid of density less than 1·50 will not detonate ; the tendency of these mixtures to explode decreases as the concentration of the acid used in preparing them decreases, and as the ratio of acetic anhydride to perchloric acid increases. A spark or a red-hot wire will not cause an explosion, but a solution rich in acetic anhydride will burn, and as there is a tendency for the rate of combustion to increase more and more there is a danger of an ultimate explosion. Metallic ions in the solution are not dangerous, organic matter in solution should be excluded. The organic insulators for the polishing baths should be carefully chosen ; ebonite or chlorinated rubber seem to be more suitable than substances based on cellulose esters.—A. E. C.

The Safe Use of Perchloric-Acetic Electropolishing Baths. P. A. Jacquet. (Metal Finishing, 1949, vol. 47, Nov., pp. 62–69). This paper is, in the main, an abridged version of the report by L. Médard, P. A. Jacquet, and R. Sartorius in Revue de Métallurgie, Mémoires, 1949, vol. 46, Aug., pp. 549–560 (*see* preceding abstract).—R. A. R.

Electrolytic Polishing of Metallic Surfaces. P. A. Jacquet. (Metal Finishing, 1949, vol. 47, May, pp. 48–54 ; June, pp. 83–92 ; July, pp. 58–64 ; Sept., pp. 60–67 ; Oct., pp. 68–73). An account is given in Part I of the discovery, principles, and mechanism of electrolytic polishing. Part II describes in detail the application of electrolytic polishing to the preparation of metallographic specimens. There is an extensive bibliography. Part III discusses the physicochemical nature of mechanically polished surfaces. In the case of steel, progressive electrolytic polishing of a surface of steel abraded with emery shows a cold-deformed layer several microns deep affecting only the ferrite, the harder pearlite remaining apparently unaffected. Micrographs of sections perpendicular to mechanically polished surfaces are shown ; these reveal the depth of the disturbed layer. Several advantages of electrolytic polishing over mechanical methods for preparing metallographic specimens are pointed out. In Part IV the principal fields of the physical chemistry of metals in which investigation is considerably facilitated by electrolytic polishing are reviewed. It is shown in Part V that there is considerable difference in the results of corrosion tests when the metal surfaces are prepared by mechanical and by electrolytic methods.—R. A. R.

New Cut-Wire Shot Big Boon to Peening. H. H. Miller. (SAE Journal, 1949, vol. 57, Aug., pp. 44–51). Shot made by cutting up 0·45–0·70% carbon hard-drawn steel wire cut in

lengths equal to the diameter (0·0348 in.) have been compared with chilled cast-iron shot for shot-peening motor car chassis springs and found to have many advantages. The cost of the former was nearly four times that of the latter, but a given weight of wire shot would treat ten times as many springs.—R. A. R.

Metal Cleaning Bibliographical Abstracts. J. C. Harris. (American Society for Testing Materials, 1949, Special Technical Publication No. 90). This publication contains nearly 500 abstracts from the literature on metal cleaning. They are arranged in chronological order from 1922 and there are separate indexes of subjects, authors, specifications, and patents.—R. A. R.

PROTECTIVE COATINGS

Protective Metallic Coatings and Their Uses in the Struggle Against Corrosion and Wear. R. J. Marimon. (Dyna, 1949, vol. 24, Sept., pp. 331–346). [In Spanish]. Constitution and properties of metallic coatings and the manner of their formation and deposition are discussed. Coatings for protection against atmospheric and chemical corrosion and elevated temperatures, and the use of hard-facing are described.—R. S.

The Structure of Electrodeposits. J. J. Dale. (Australian Institute of Metals: Metal Industry, 1949, vol. 75, Oct. 21, pp. 355–357; Nov. 4, pp. 394–395). The present state of knowledge of the structure of electrodeposits is reviewed and subjects for future research are suggested.—R. A. R.

Automatic Plating Plant Design. A. Smart. (Metal Industry, 1949, vol. 75, Nov. 18, pp. 433–435; Dec. 2, pp. 476–478). Fundamentally every electroplating plant is a conveyor mechanism which in principle has to perform two functions, one a simple straight-through motion, and the other a transfer motion from one tank to the next. The implications of this and their influence on plating plant design are considered. Automatic plating can also be applied to the barrel plating of small parts. In one of these a horizontal cylinder has an internal archimedean screw of non-conducting plastic material. Suitable cathodically charged contact elements come into contact with the work which draws current from the anode passing through the centre of the barrel beneath the surface of the solution.—R. A. R.

New Developments Noted in Corrosion-Resistant Coatings and Rare Metals. (Steel, 1949, vol. 125, July 11, pp. 90–94, 96). This is a review of some of the papers presented at the 95th Convention of the Electrochemical Society, May 4–7, 1949. In one, salt-bath chromizing, in a bath of 30% $CrCl_2$, 49% $BaCl_2$, and 21% NaCl, is compared with the present pack-chromizing method: thicker coatings can be obtained in less time, at comparable cost. The electrodeposition of rhenium and tantalum is also discussed; whereas the former may be readily deposited from sulphuric acid, citric acid, or ammoniacal citric acid baths, all containing potassium rhenate, the deposition of the latter metal from aqueous solution is still unattained. The melting and casting of zirconium in the arc-furnace, high-frequency furnace, and graphite-resistor furnace is described; using the first type, ingots containing only a trace of tungsten and 0·02–0·07% of carbon have been produced. Papers on the theory of passivity and inhibition in metals and on the corrosion resistance of stainless steel were also presented.—J. P. S.

Protective Coatings. G. E. Seidel. (Steel Processing, 1949, vol. 35, July, pp. 368–370). The paper makes general recommendations on the selection of a coating to resist particular conditions, surface preparation, and method of application. R. A. R.

Cleaning Plating Baths with Active Carbon. (Metalloberfläche, 1949, vol. 3, Aug., p. B-69). The procedures for using active carbon for the batch and the continuous cleaning of plating solutions are described.—R. A. R.

Disposal of Plating Room Wastes. I—A Critical Review of the Literature Pertaining to the Disposal of Waste Cyanide Solutions. (Plating, 1949, vol. 36, May, pp. 463–469, 512; June, pp. 571–577, 664; July, pp. 723–732; Aug., p. 827).

X-Ray Method for the Determination of the Thickness of Coatings by Means of Superimposing. L. S. Palatnik. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1043–1054). [In Russian]. An X-ray method of determining the thickness of coatings on metals and alloys is described which is based on the comparison of the intensities of Debye lines of the coating and of the coated material; allowance is automatically made for the nature of the crystals comprising these materials. The accuracy of results obtained by this method is considered and a specially suitable camera is described. An account is given of the application of the method to the determination of the thickness of oxide coatings on silicon steel and blued steel.—S. K.

A Handy Coating-Thickness Meter of High Accuracy. R. Berthold. (Zeitschrift des Vereines deutscher Ingenieure, 1949, vol. 91, Sept. 15, pp. 476–478). A simple instrument for measuring the thickness of coatings of non-ferrous metals, paints, and enamels on a ferromagnetic base is described. It consists of a cylindrical case, about the size of a pencil, containing a movable bar surrounded by a light coil spring. The bar carries a permanent magnet at one end which projects beyond the case and has fixed to it a spherical shoe of high-permeability material. The bar is notched at suitable intervals and a spring catch locks it in the extended position on the instant of its removal from the surface. The instrument is held vertically on the coating to be measured and the magnetic force compresses the spring as it extends the bar by an amount depending on the thickness of the coating. The magnitude of the movement for a given coating thickness is very much greater with the high-permeability shoe than without it.—R. A. R.

Determination of Coating Weights on Electrolytic Tinplate. H. Liebmann, J. W. Price, and S. R. Thompson. (Journal of the Society of Chemical Industry, 1949, vol. 68, June, pp. 177–179). Commercial electrolytic flow-brightened tinplate of nominal 8 oz. per basis box coating weight is shown to contain a tin–iron alloy at the interface. The extent of this alloy has been determined and a suitable correction is suggested for coating-weight determinations on this material by loss of weight in antimony-chloride/hydrochloric acid.—R. A. R.

Examination of Methods of Precipitating Zinc out of Nickel Baths. (Metalloberfläche, 1949, vol. 3, June, p. B40). The Liscomb method of precipitating zinc impurities in nickel-plating baths is not recommended; of the precipitation methods only the nickel carbonate method is advocated. R. A. R.

A Theory for the Mechanism of Chromium Plating; A Theory for the Physical Characteristics of Chromium Plate. C. A. Snavely. (Transactions of the Electrochemical Society, 1947, vol. 92, pp. 537–577). A general study of the structural characteristics of chromium plate and the mechanism of chromium plating has been made. The plating conditions can be adjusted so that chromium is deposited either as metal in the body-centred cubic arrangement, as a hydride in the hexagonal arrangement, or as a hydride in the face-centred cubic arrangement. The hydrogen atoms are interstitially placed in the hydrides. The body-centred cubic plates are stable, but the hydrides are structurally unstable and decompose with shrinkage in volume to form body-centred cubic metal and hydrogen.

It is postulated that commercial hard chromium plate is 'cracked' because of the successive deposition of hexagonal hydride and its decomposition during plating. As this cracking occurs 'cathode film' is drawn into the shrinkage cavities to fill them with a compound of partially reduced chromium. These physical effects are governed by the cathode film.

The cathode film is postulated as consisting principally of a 'colloidal membrane' of such composition and disposition that its isoelectric point is within the *p*H range operative at the cathode surface. At the low end of this range, body-centred cubic chromium is deposited; at intermediate *p*H levels, hexagonal hydride is deposited; and at the high end, face-centred cubic hydride is deposited.

X-ray data are presented to support the concept that the hydrides are not merely metallic chromium containing dissolved hydrogen.—R. A. R.

Salt-Bath Chromizing. I. E. Campbell, V. D. Barth, R. F. Hoeckelman, and B. W. Gonser. (Journal of the Electrochemical Society, 1949, vol. 96, Oct., pp. 262–273). Successful salt-bath chromizing has been carried out on Armco iron, plain carbon and low-alloy steels, and cast irons. Smooth, non-porous, deformable, and nitric-acid-resisting cases were produced at temperatures between 900° and 1200° C. with chromous chloride concentrations of fr to 30% by weight, in periods of from 1 to 6 hr. The rate of formation of the case was equal to or faster than the various pack methods at corresponding temperatures. This process compares favourably with other methods from the point of view of costs.—R. A. R.

Cadmium as an Intermediate Layer for the Bright Chromium Plating of Iron and Steel. K. Kufferath. (Archiv für Metallkunde, 1949, vol. 3, June, p. 225). The plating conditions for producing a bright cadmium coating on iron and steel are described.—R. A. R.

The Elastic Modulus and the Strength of Hard Chromium Coatings. W. Eilender, H. Arend, and E. Schmidtmann. (Metalloberfläche, 1949, vol. 3, July, pp. A-145–A-147). The elastic modulus of hard chromium electrodeposited coatings was determined by tensile and bend tests and found to be 16,400 kg./sq. mm. Annealing at up to 300° C. reduced it to about 13,000 kg./sq. mm. After annealing at higher temperatures the change in the modulus is very small. The tensile strength was 15 kg./sq. mm.; no elastic limit could be found. R. A. R.

The Efco-Udylite Bright Nickel Plating Solutions. H. J. Bache. (Industrial Finishing, 1949, vol. 2, Sept., pp. 105–113). Preliminary cleaning of the surface and bright nickel-plating by the Efco-Udylite process are described. The cleaning is most important and the solution and procedure for this should be selected to suit the material to be plated. There are two Efco-Udylite plating solutions: (*a*) The No. 31 bath which is basically a Watts type solution with additions of brighteners and a wetting agent; and (*b*) a high-chloride solution with the same additions. Solution (*a*) can tolerate a zinc concentration of only 0·1–0·15 g./l. of crystalline zinc sulphate, whereas (*b*) may contain up to 0·9–1·2 g./l. The operating temperature for (*a*) is 115–140° F. and for (*b*) 135–145° F. R. A. R.

Determination of Impurities in Electroplating Solutions. XIII—Traces of Zinc in Nickel Plating Baths. (Plating, 1949, vol. 36, Aug., pp. 818–823). Continuation of a series of articles, *see* Journ. I. and S.I., 1949, vol. 163, Oct., p. 229. A colorimetric method using dithizone has been developed for determining traces of zinc. Copper and iron are first removed by the formation of their cupferrides and their extraction with amyl acetate. Heavy metal impurities are then complexed with sodium di(β-hydroxyethyl)dithiocarbamate. Zinc dithizonate is formed in the presence of these complexes when a carbon tetrachloride solution of dithizone is added. After removing the excess dithizone, the zinc is determined colorimetrically.—R. A. R.

Nickel-Clad Steel. (Sheet Metal Industries, 1949, vol. 26, Sept., pp. 1894–1896). The process of cladding steel plate with a sheet of nickel, developed by the Lukens Steel Co., U.S.A., is now operated in Great Britain by the Steel Company of Wales, Ltd. The preparation and rolling of the 'sandwich' of two steel plates with two nickel sheets in between separated by a mixture of magnesium oxide and sodium silicate, are described. Brief details are also given of the technique for welding nickel-clad steel. A **V**-cut from the steel side down to the nickel is filled with steel welding, after which the nickel surface is chipped well down to the weld metal and the groove filled with nickel.—R. A. R.

Protective and Decorative Nickel Plating of Articles without After-Polishing. N. T. Kudryavtsev, O. M. Korol'kova, and V. V. Fedurkin. (Zhurnal Prikladnoi Khimii, 1949, vol. 22, June, pp. 586–591 [in Russian]: [Abstract] Bulletin of the British Non-Ferrous Metals Research Association, 1949, Oct., p. 423). Experiments on the use of alkali metal salts of naphtalene 2,6- and 2,7-disulphonic acids as brighteners in nickel plating are reported. Bath compositions and conditions are recommended.

Purification of Nickel Plating Baths by Activated Charcoal. M. Ballay and P. Mainçon. (Revue du Nickel, 1949, vol. 15, July–Sept., pp. 65–69: [Abstract]. Bulletin of the British Non-Ferrous Metals Research Association, 1949, Oct., p. 423). Impurities found in nickel-plating baths include fine particles of various metallic substances in solution, colloidal particles, and certain oils. The nature and properties of activated charcoals and methods of using them for purification, the addition of activated charcoal to the bath followed by filtration, intermittent filtration over activated charcoal, and continuous filtration are discussed.

Rapid Method of Determining Nickel on the Surface of Enameling Iron. L. C. Ikenberry and J. J. Canfield. (Journal of the American Ceramic Society, 1949, vol. 32, Oct., pp. 308–312). A photometric method for determining nickel on nickel-coated steel is described. The method requires less than 5 min. The standard deviation (σ) has been found to be 0·0028 g. of nickel per sq. ft. when testing a sheet carrying 0·10 g. of nickel per sq. ft. The sample is obtained by dissolving the nickel coating on a small area with dilute nitric acid. The nitric acid is confined by using a weighted rubber ring and is withdrawn by suction into a 200-ml. Erlenmeyer flask marked at 200 ml. A large excess of ammonium hydroxide is added, followed by ammonium persulphate and dimethylglyoxime. The solution is diluted to 200-ml. with water. After filtering off the ferric hydroxide the intensity of the red colour, which is proportional to the amount of nickel present, is measured by means of a photoelectric photometer.

Some Applications of Continuous Hot-Dip Galvanising. H. Bablik. (Sheet Metal Industries, 1949, vol. 26, Aug., pp. 1657–1660). The continuous hot-dip galvanizing processes described include the 'flame-sealed' process of Julius L. Schueller for wire in which the product is annealed in a series of flames after the dip; the R. Haarman process for tubes with special conveyors for moving the tubes in and out of the bath; and the Sendzimir process for cold-rolled strip in which the thin layer of scale is removed by reduction in hydrogen produced by cracking ammonia.—R. A. R.

Distribution of Metal on the Cathode Surface in Zincate [Tin-Containing] Electrolytes. N. T. Kudryavtsev and A. A. Nikiforova. (Zhurnal Prikladnoi Khimii, 1949, vol. 22, Apr., pp. 367–376 [in Russian]: [Abstract] Bulletin of the British Non-Ferrous Metals Research Association, 1949, Oct., p. 423). The throwing power of the electrolyte (which contained 0·25–0·5 g./l. tin to improve the brightness, density, and adhesion of the deposit) was investigated by measuring the thickness of the deposit at various points of the cathode (a strip bent to form a **Z** with 60° corners). The influence of bath composition (free alkali, zinc), temperature, and current density was studied and data for cyanide and acid baths are included.

Electrogalvanizing in Zincate Electrolytes at Increased Current Densities. N. T. Kudryavtsev, A. J. Lipovetskaya, and K. N. Kharlamova. (Zhurnal Prikladnoi Khimii, 1949, vol. 22, Apr., pp. 377–384 [in Russian]: [Abstract] Bulletin of the British Non-Ferrous Metals Research Association, 1949, Oct., p. 424). Experiments on the influence of various addition agents, and of agitation, on the permissible current density and the throwing power of the bath are described.

Galvanized Welds. (Pacific Marine Review, 1949, vol. 46, Aug., p. 62: [Abstract] Journal of The British Shipbuilding Research Association, 1949, vol. 4, Oct., pp. 447–448). A description is given of a process of galvanizing welds known as Galv-Weld. It is intended for application to localized areas without the trouble of hot-dipping large or complicated assemblies. Galv-Weld is a stick of low-melting zinc-base alloy which quickly and easily re-galvanizes structures and sheets from which the galvanizing has been burned off during the welding process. The material is merely rubbed over the heated surface and melts to leave an adherent coating of zinc alloy. It is claimed that this process requires no flux or sandblasting, makes no fumes, will not peel or chip, and makes a bond to the base metal that is actually superior to zinc metal spray. No special equipment is necessary, and the work can be done anywhere in any position and in confined quarters. It has successfully withstood a 141-day salt-water test. The process can be applied to simplify and improve design in many cases.

Production of Tin Plate. A. E. Kadell. (Steel, 1949, vol. 125, Aug. 1, pp. 82–88; Aug. 8, pp. 84–92; Aug. 15, pp. 114–124). The production of tinplate by continous hot-dip and electrodeposition, from the receipt of the coiled strip to the packing of cut sheet for export, is very fully described and illustrated.—J. P. S.

The Bullard-Dunn Electrolytic Descaling and Tinplating Process. (Tin and Its Uses, 1949, Oct., pp. 3–4). The Bullard-Dunn tinplating process (patented by the Bullard Company of Bridgeport, Conn.) is described. The feature of the process is that the descaling bath, consisting of dilute sulphuric acid, uses a tin salt as inhibitor. The work is made cathodic in a circuit of high current denstiy and, in consequence, as soon as scale or oxide is removed a fine layer of tin is deposited in its place.—R. A. R.

Hot-Tinning. W. E. Hoare. (Tin Research Institute, 1949). This 112-page booklet, intended primarily to meet the needs of the operator, foreman, engineer, and designer, comprises nine chapters, the first being an introduction and the others covering the following aspects: (II) Operations and plant; (III, IV, V, VI, and VII) the

tinning of steel, cast iron, copper, other metals, and tinning with tin–lead alloys, respectively: and (IX) methods of determining the thickness and continuity of tin coatings.
R. A. R.

A High-Efficiency Anode for Alkaline Tin-Plating. F. A. Lowenheim. (Journal of the Electrochemical Society, 1949, vol. 96, Oct., pp. 214–225). The effect of 26 elements on the anodic behaviour of tin in alkaline stannate baths has been shown. The aluminium alloys are of principal practical interest, and about 1% of aluminium markedly improves the anode efficiency, thereby extending the range of usefulness of potassium stannate electrolytes. Other minor additions to tin also appear to have some beneficial effects, but all except aluminium have some drawbacks. Some metals, notably cadmium, indium, and nickel have a strong passivating action and should be kept out of tin anodes. The aluminium–tin anode has been sufficiently tested to warrant recommending its commercial application.—R. A. R.

Electrolytic Tinplate—Its Production and Benefits. S. S. Johnston. (United Nations Scientific Conference on the Conservation and Utilization of Resources: Sheet Metal Industries, 1949, vol. 26, Sept., pp. 1962–1964). The economic aspects of producing tinplate by the electrolytic process are discussed with special reference to cost of raw materials, labour, maintenance, overhead charges, depreciation, and amortization. In spite of the fact that the capital investment for the plant is two and a half times that for hot-dip equipment of equivalent capacity, the speed of production, ease of control, and thinness and uniformity of coating obtained by the former process give it an economic advantage.
R. A. R.

Determination of Cottonseed Oil on Tin Plate. J. G. Donelson and R. Neish. (Analytical Chemistry, 1949, vol. 21, Sept., pp. 1102–1104). Cottonseed oil is sprayed on to tinplate to inhibit oxidation during storage and assist subsequent forming operations. The hydrophil balance may be used to estimate the quantity present. Here, the film of oil is transferred, by dipping, to the surface of water in a tray. A movable barrier then compresses the oil film laterally so that it bears against another barrier, where the torque is measured by the deflection of a wire and pointer. The instrument is calibrated with a known weight of oil.—J. P. S.

The Electrodeposition of Molybdenum Alloys. H. J. Seim and M. L. Holt. (Journal of the Electrochemical Society, 1949, vol. 96, Oct., pp. 205–213). A new aqueous citrate plating bath for the electrodeposition of alloys of molybdenum with cobalt, iron, and nickel is described. This type of solution contains the sulphate of the codepositing metal, citric acid, and sodium molybdate. Ammonium hydroxide is used for adjusting the *p*H. A bath temperature of about 25° C. is preferred. The highest percentage of molybdenum (about 50% and more) is obtained with iron as the codepositing metal, and the lowest is with nickel.—R. A. R.

The Building Up of Galvanic Alloy Deposits. VI. The Cadmium–Zinc Alloys. E. Raub and B. Wullhorst. (Zeitschrift für Metallkunde, 1949, vol. 40, July, pp. 266–270). The deposition and properties of cadmium–zinc alloy coatings has been studied by plotting cathode-potential/current-density curves under various plating conditions and making microscopical, X-ray, and hardness tests. Zinc and cadmium were deposited simultaneously from cyanide and acid baths only when the cathodic current density exceeded the limiting current density for cadmium deposition. The deposition potential of the two metals in alloy plating baths has the same value as with baths for the separate metals. Cadmium and zinc crystallize simultaneously but in separate crystals side by side. No solid solution could be found by X-rays and the microscope. The hardness of alloy deposits is an average of the softer cadmium and the harder zinc crystals.—R. A. R.

Sprayed Steel Coatings and the Steel Coating of Aluminium. J. Cauchetier. (Revue de l'Aluminium, 1949, vol. 26, May, pp. 171–172). A brief description is given of a method of spraying steel coating on to aluminium and magnesium, with an account of the properties and structure of the layer.—J. C. R.

Reclamation of Worn Parts by Metal Spraying. A. E. Williams. (Mechanical World, 1949, vol. 125, June 17, pp. 693–696). The preparation of the surface to receive sprayed metal, the spraying process, and several applications relating to the repair of worn parts, are described.—R. A. R.

The Development of Metal-Spraying Technique since 1938. K. Krekeler. (Schweissen und Schneiden, 1949, vol. 1, Sept., pp. 153–158). The literature on the metal-spraying process is reviewed and descriptions of gas-heated and electrically heated spraying pistols are given.—R. A. R.

New Metallizing Techniques Offer Production Economies and Simplified Design. J. E. Wakefield. (Iron Age, 1949, vol. 164, Sept. 8, pp. 80–84). The uses and possibilities of metal spraying are described. New techniques include the metering of the oxygen and acetylene used in the spraying pistol, which is claimed to increase the speed of operations, and the use of spraying in the production of electric circuits for radios and similar apparatus.—J. P. S.

Corrosion Resistance of Sprayed Metal Coatings. W. S. Meyer. (Corrosion, 1949, vol. 5, Sept., pp. 282–287). The metal-spraying process and results obtained with it are discussed. Fourteen carbon steel bars $1\frac{5}{8}$ in. in dia. were sprayed with 23/14, 24/21, and 19/25 nickel–chromium steels and the compositions of the coatings were compared with those of the initial wire used in the spraying pistol. There was an increase in the carbon of about 0·01%, no change in phosphorus and sulphur, a very slight loss in silicon, a loss of 0·20–1·00% in nickel, a loss of 0·50 to 1·00% in chromium, and no change in molybdenum. Methods of making heat-resisting coatings are also described; one process consists of grit-blasting the steel surface, metallizing with 0·006 in. of aluminium, applying a bitumastic sealing compound, and heat-treating at 1450° F. to form a solid solution of aluminium in iron. This coating will resist attack by hot sulphur-containing gases.—R. A. R.

Flame-Sprayed Polythene Coatings Provide Exceptional Corrosion Resistance. (Materials and Methods, 1949, vol. 30, Sept., p. 81). The technique for spraying metal with polythene resin is described. The surface to be sprayed must be preheated to 400–500° F. to achieve proper flattening and coalescence of the particles and the flame from the pistol should be 8–12 in. long, the tip being kept about 2 in. from the surface of the work.—R. A. R.

A New Bonding Resin. Detailed Results of Laboratory Tests on "Araldite." (Sheet Metal Industries, 1949, vol. 26, Sept., pp. 1967–1988). The applications of Araldite as a synthetic coating material have already been reported (*see* Journ. I. and S.I., 1949, vol. 162, July, p. 363). The present article reports the results of tests on the strength and deformation properties of single-lap, double-lap, and butt joints made with Araldite resin on non-ferrous metals, mild steel sheet, and stainless steel sheet. Araldite, which is pasty at about 90° C. and liquid at about 120° C., enables an integral bond to be made with lapped metal sheets merely by curing at 200° C. for 1 hr. In the case of light alloys and standard structural steels of small and medium thicknesses the joint is equal or even superior to riveted or welded joints with respect to both static and fatigue stresses.—R. A. R.

The Protection of Ferrous Metals from Corrosion. J. A. D. Hutton. (Industrial Finishing, 1949, May, pp. 615–621; June, pp. 691–698; July, pp. 784–789). The following coating processes for protecting iron and steel against corrosion are briefly described in the first part: (1) The production of black oxide coatings by (*a*) Negradizing salts, and (*b*) Aquablack; (2) magnetic iron oxide coatings by the Bower-Barff process; (3) Coslettizing; (4) Parkerizing; (5) Bonderizing; (6) Granodizing; (7) Walterizing and Jenolizing—both phosphatizing processes; and (8) Ferroclening. The second part describes hot-dipping processes for coating with tin, zinc, lead, and aluminium; metal spraying; cementation; Sherardizing, chromizing, Calorizing, and aluminizing. The third part deals with enamels, paints, varnishes, and lacquers, and explains the mechanism of drying.—R. A. R.

The Porosity and Rate of Formation of Electrodeposited Phosphate Coatings. W. Machu. (Archiv für Metallkunde, 1949, vol. 3, Aug., pp. 278–281). The porosity and rates of formation of phosphate coatings, using Granodine and Bonder solutions with and without A.C. polarization, were determined. The combined effects of chemical and electrochemical acceleration were also studied. The accelerations due to A.C. and to additions such as nitrites or nitrates are additive. The optimum coating time of about 2 min. cannot be achieved by chemical means alone. Electrodeposited phosphate coatings are in general somewhat more porous than those obtained in the same bath without current, but this small difference is of little practical importance as subsequent coatings of oil or lacquer are usually applied.
R. A. R.

Manganese Phosphate Coatings from a Short-Time Bath. W. Machu. (Archiv für Metallkunde, 1949, vol. 3, Aug., pp. 283–286). The rate of coating formation and the porosity in the nitrate-containing manganese phosphate bath were investigated by an electrochemical method of porosity testing. The pore area became constant after 15 min. phosphatizing. With fresh solution the pore area was greater than with the zinc phosphate bath, but with use the pore area rapidly diminished and became even less than with the latter bath. The corrosion resistance of manganese phosphate coatings varies inversely with the pore area ; this resistance can be increased by a subsequent chromate treatment.

R. A. R.

Phosphate Processes for Iron and Steel with Special Reference to Rust-Proofing. E. E. Halls. (Metallurgia, 1949, vol. 40, July, pp. 159–161 ; Aug., pp. 193–199). Having described the advantages of phosphate coatings and the process of phosphatizing in the first part, the author, in the second part, presents and discusses the results of several kinds of tests on steelwork with a variety of combinations of coatings with and without pretreatment by phosphatizing. Salt-spray tests showed the improvement in resistance with phosphatizing. R. E. Shaw's paper on phosphate coatings to increase the wear resistance of machinery parts is extensively quoted (*see* Journ. I. and S.I., 1947, vol. 156, May, p. 138).—R. A. R.

Surface Treatment. (Diesel Power, 1949, vol. 27, June, p. 58 : [Abstract] Journal of The British Shipbuilding Research Association, 1949, vol. 4, Sept., p. 421). Examples are quoted to illustrate the effectiveness of the Parco Lubrite process for treating cast iron and steel parts of Diesel engines in speeding up the running-in process of mating parts, with a reduction of scuffing during this period and of subsequent wear. The treatment involves an acid-etching process in which a non-metallic coating is formed, principally of iron and manganese phosphates. Microscopic examination of the dull matt-finished surface reveals countless etched pores which act as tiny oil reservoirs. Many of these remain even after the coating has worn away. Meanwhile the surface has been brought to the desired finish, and wear will be retarded. The coating acts as a mild abrasive during the running in. Treated and untreated gears were run in a comparative test. Within 10 hr. the untreated gears showed signs of scuffing and scratching, while the surfaces of the treated gears were still unmarked after 300 hr. Valve stems with 20 to 35 microfinish were found to work satisfactorily in conjunction with coated guides which were either reamed or broached, whereas in combination with untreated guides, stems with this degree of finish failed consistently.

The Kinetics of Coating Phenomena, Especially Those of the Phosphatizing Process. W. Machu. (Archiv für Metallkunde, 1949, vol. 3, June, pp. 203–208). An attempt is made to develop a formula for the rate of formation of protective coatings on iron.—R. A. R.

The Theory of Phosphatizing. A. Wüstefeld. (Archiv für Metallkunde, 1949, vol. 3, July, pp. 253–255). The theoretical bases for phosphatizing in acid and in alkaline baths are shown to be the same. In both cases there are present complex solutions in which colloids are formed by elimination of the H and OH ions, the colloids being positively charged and the metal negatively. This results in flocculation of the colloids on the metal surface at first as a highly dispersed layer which subsequently builds up.—R. A. R.

Adsorption and Absorption by Surface Films, Especially Phosphate Films, and Their Plasticity. H. Wüstefeld. (Archiv für Metallkunde, 1949, vol. 3, June, pp. 223–224). Experiments are described which indicate the manner in which soap solutions are adsorbed by phosphate coatings.

R. A. R.

The After-Treatment of Phosphate Coatings with Chromates. W. Machu. (Archiv für Metallkunde, 1949, vol. 3, July, pp. 250–253). The treatment of phosphate coatings with (*a*) sodium monochromate, (*b*) potassium bichromate, and (*c*) chromic acid reduces the porosity and increases the corrosion resistance of phosphate coatings, the effect increasing in the order *a*, *b*, *c*. The increase in the corrosion resistance is not due only to the reduced porosity, but mainly to the passivating influence of the chromate.

Review of Titanium Enamel Development and Discussion of Its General Properties. D. R. Goetchius. (Proceedings of the Porcelain Enamel Institute Forum, 1948, 10th Forum, pp. 7–11, 15–21 : American Ceramic Abstracts, 1949, Sept., p. 204).

Production Application of Titanium Enamels. H. C. Wilson. (Proceedings of the Porcelain Enamel Institute Forum, 1948, 10th Forum, pp. 12–21 : American Ceramic Abstracts, 1949, Sept., p. 204).

Shop Processing of Titanium Enamels Direct on to Titanium Steels. J. L. Lannan. (Proceedings of the Porcelain Enamel Institute Forum, 1948, 10th Forum, pp. 27–31, 46–51 : American Ceramic Abstracts, 1949, Sept., p. 204. Early tests of titanium enamels directly on titanium steel were made in May, 1947. A nickel dip and a lower-maturing enamel were needed before they could be used in regular production. No difficulties were found in the fabrication of items, especially if the parent metal was used in the gas welding of parts. The enamelling procedure is essentially the same as with other enamels, except that greater care must be exercised to keep the parts clean, free from scratches, and smoothly enamelled. The thin coating shows the scratches more, and without a base coat the enamel does not tend to level out during firing as well as it does with a base coat. Several causes of defects and methods of eliminating them are discussed. In general, the opacity, adherence, and lack of crazing, chipping, and other defects, plus the lower plant costs, make titanium enamelling on titanium steels very desirable.

Pickle and Mill Room Practice and Procedure for Application of Titanium Enamel Direct to Titanium Steel. J. C. Swartz. (Proceedings of the Porcelain Enamel Institute Forum, 1948, 10th Forum, pp. 32–37, 46–51 : American Ceramic Abstracts, 1949, Sept., p. 204). Considerably greater care in the general handling of titanium enamels is necessary because of their somewhat narrower firing range, susceptibility to impurities, and greater expense. In addition, a nickel dip is necessary in applying titanium enamels direct on to titanium steel. A detailed description of the pickling and mill-room procedure is presented with data on installations and equipment. The use of reclaimed enamel on the back of ware is also described.

Effects of Some Electrolytes on Color Value of Enamels Made from a Standard Titania-Opacified Frit. E. A. Marbaker, H. S. Saunders, and L. N. Baumer. (Journal of the American Ceramic Society, 1949, vol. 32, Sept. 1, pp. 297–304). Just as the properties of titania enamels are influenced by the clay used as the suspending agent in slip preparation, so it was thought that the salts used as electrolytes might also have effects of a similar nature. Six salts, KCl, K_2CO_3, $NaAlO_2$, $NaNO_3$, $MgCO_3$, and KNO_3, more or less commonly used as electrolytes for setting up titania enamels, were employed singly and in combinations of two and three in the preparation of 25 slips made from a standard frit. The clay content was 4%, and the milling conditions were constant. Slips that, therefore, varied in electrolyte content only, were sprayed on ground-coated steel plates, which were then fired uniformly. The set of the slips was determined by means of the Irwin slump test and the Brookfield viscometer. The reflectance, colour value, finish, and acid resistance of the enamels were found by standard methods. The results showed that electrolytes have much more effect on enamel properties than has commonly been supposed and that, in the preparation of enamels, not only the quality of the frit but the properties of the components of the mill addition, clay and electrolyte alike, merit careful consideration in order to achieve the best possible results.

Enamelled Low-Carbon Steel for Chemical Plant. K. Frick. (Chemie, Ingenieur, Technik, 1949, vol. 21, July, pp. 249–258). The use of enamel coatings has been extended from the protection of cast iron to low-carbon steel in many forms, such as tubes, pressure vessels, heat exchangers, and filters ; these are reviewed. The properties of enamel and methods of application are discussed, and recommendations on the assembly of enamelled steel pipelines, valves, etc., are made.—R. A. R.

An Investigation into the Factors Affecting the Adhesion of Vitreous Enamel to Arc-Welded Mild Steel. E. Bishop. (Sheet Metal Industries, 1949, vol. 26, Aug., pp. 1755–1760). An investigation was made of means of preventing the blistering of enamel over welds in steel sheets in the manufacture of refrigerator linings. The blistering of vitreous enamel is due to the evolution of hydrogen from the seams. The hydrogen is present in the atomic form in the metallic

lattice structure and in the molecular form and/or as water vapour associated with slag inclusions and porosity. The atomic hydrogen can be removed rapidly by heating, and is eliminated during the grease-firing preceding enamelling. The molecular hydrogen is much more resistant to removal and is evolved during the high-temperature heating of the enamel firing. The latter type of hydrogen is eliminated by using a special electrode, the deposit from which is free from porosity and slag inclusions. The problem of welding very thin mild-steel sheet by the arc process so that the underside of the weld is uniform and capable of being enamelled satisfactorily, has been solved by the use of a tight-fitting heavy solid copper backing bar.—R. A. R.

Stamping and Enameling Improves Products. T. A. Dickinson. (Steel Processing, 1949, vol. 35, Aug., pp. 413, 414, 434). A brief account is given of the equipment and processes at the works of the U.S. Porcelain Enamel Co., Los Angeles, which has machines for shaping iron and steel sheets and spraying equipment for enamelling. A method of producing decorative designs by forcing a semi-fluid coating material through a silk screen stencil is described.—R. A. R.

Spot Test for Chemical Resistance of Enamelled Surfaces. J. T. Roberts. (Journal of the American Ceramic Society, 1949, vol. 32, Aug., pp. 243–245). A theoretical relationship between the colour and thickness of thin films of amorphous silica was established. An acid-resistance test based on this relationship was developed and applied to testing of enamelware. According to the results obtained thus far, the colour changes that are actually brought about by chemical attack agree with those which should occur theoretically. The test method thus appears to be fundamentally sound, at least in so far as this point is concerned. Its application to the testing of an enamel at different temperatures, as well as in the testing of various types of enamels at constant temperature, appears to afford satisfactory results. Enamel No. 41, when exposed for 48 hr. to a solution of 20% HCl at 60° F., developed, according to this method of test, a film about 675 Å. thick. At 100° F. the film reached a thickness of about 2550 Å. In the constant-temperature tests the various types of enamels developed films in 2 hr. that ranged from 60 to 2750 Å in thickness.

Enamelling Defects on Sheets. P. Tyvaert. (Fonderie, 1949, Apr., p. 1560). A brief practical note is presented on the prevention of enamelling defects on sheets.—J. C. R.

Carbon as the Source of Defects in Enamelling. W. Engelhardt. (Metalloberfläche, 1949, vol. 3, July, pp. A-141–A-145). The causes and prevention of blisters and craters in enamel coatings are considered. These defects are due to the evolution of gas arising from the oxidation of carbon. The following measures are recommended: (1) Adding an oxidizing agent to the enamel when preparing it in order to oxidize any free carbon present; (2) removing any residual drawing lubricant from the steel by burning, followed by chemical and mechanical cleaning; (3) not dusting the mould with graphite in the case of cast-iron articles to be enamelled; (4) adopting a steelmaking practice which minimizes carboniferous slag and inclusions; (5) annealing so as to convert cementite in the grain boundaries into the spheroidal form; and (6) reducing the cementite in cast iron to 10% or less of the total carbon by selecting a suitable composition and heat-treatment.

Mottled Enameled Finishes Obtained by Precipitation of Various Color-Producing Salts. G. Sirovy and E. P. Czolgos, (Bulletin of the American Ceramic Society, 1949, vol. 28. June 15, pp. 223–224). Coloured mottle finishes resembling marble were developed in sheet steel cover-coat enamels by precipitating various mottling salts incorporated in the enamel. Mottles were developed in lavender, blue, green, yellow, red, burgundy, brown, and ivory colours.

Electrochemical Studies of Protective Coatings on Metals. Part II—Resistance and Capacitance Measurements on Painted Steel Immersed in Sea Water. F. Wormwell and D. M. Brasher. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 141–148). Alternating-current measurements of electrical resistance and capacitance have been used to investigate the behaviour of painted steel immersed in sea water. The changes in these electrical properties have shown good correlation, throughout the whole period of breakdown of the paint, with the incidence and progress of corrosion of the underlying metal. The technique has been used to investigate the influence of the type of paint, of adverse conditions during painting, and of aeration and stirring of the sea water.

An Investigation of Structural Steel Shop Coating Priming Paint. S. C. Frye. (Corrosion, 1949, vol. 5, Sept., pp. 288–291). An investigation of a number of priming paints to protect structural steel after production in the rolling mill until erection in the field is reported. Three pigmentations were used: (1) 100% of 97% grade red lead; (2) 75% of 97% red lead with 25% of 85% grade Fe_2O_3; and (3) 60% of 97% red lead, 20% of 85% Fe_2O_3, 15% magnesium silicate, and 5% mica. Eight vehicles were also tried. After 19 months' exposure, 100% red lead in linseed oil afforded the best protection, but it did not pass the requirement that the coating should dry in 8 hr. The two coatings drying within 8 hr. which gave best protection were: (*a*) pigmentation (3) in 34% phthalic anhydride linseed oil glyceryl phthalate resin, and (*b*) 100% red lead in 30% phthalic anhydride linseed oil glyceryl phthalate resin thinned with 2% by volume of a mixture of naphtha and kerosene. A primer of 100% red lead in a dehydrated castor-oil resin gave surprisingly good results in very limited tests.—R. A. R.

Electrochemical Method of Testing the Anti-Corrosion Properties of a Lacquer Paint Coating. M. M. Goldberg and N. D. Tomashov. (Zavodskaya Laboratoriya, 1949, vol. 15, Aug., pp. 951–955). [In Russian]. In the method described two circular electrodes, 60 mm. in dia., one of zinc and the other of iron, coated with the paint were immersed in a 3% aqueous solution of calcium chloride. The electrodes were connected to a milliammeter to form an electric cell and the current passing was intermittently observed. The curves of current density against time were found to be characteristic of the particular coating used, and the results obtained with various paints are presented and discussed.—S. K.

The Practical Problems of Corrosion. Part XIII—The Painting of Wet Steel Surfaces. J. E. O. Mayne and U. R. Evans. (Journal of the Society of Chemical Industry, 1949, vol. 68, July, pp. 212–215). Outdoor tests on paint specimens exposed for eight years at Cambridge showed no difference between paint applied to dry and to wetted steel surfaces. It would seem that the dangers of water have been somewhat overstressed, although water in crevices must still be regarded as a real danger. If acidic substances are dissolved in the moisture film, it can cause trouble. The results reported should not be construed as an excuse for laxity in the conditions of painting, which should be carried out on a clean dry surface.—R. A. R.

Evaluation of Paint Films. C. J. Rolle and Theresa L. Dietrich. (Analytical Chemistry, 1949, vol. 21, Aug., pp. 996–997). An instrument known as the Interchemical Adherometer is used for measuring the adherence of paint films to smooth surfaces. The method of operation consists of stripping a 4-mm. width of the paint with an ivory knife and measuring the force required. This stripping force F, however, is the sum of three components: T, the tear resistance of the paint film on both edges of the 4-mm. strip, P, the plastic resistance of the film to the pushing of the knife, and A, the force of adhesion of the paint to the metal. By removing a second strip alongside the first, so that only one edge is required to tear, T may be eliminated from the equation $F = T + P + A$, and $P + A$ put into a form related only to the forces F_1, and F_2 and the widths W_1 and W_2, in the cases of the two side-by-side strips. Now A, it is considered, is purely an interfacial attraction independent of the film thickness, while P depends solely on, and should be directly proportional to, the film thickness. By repeating the stripping on panels having a successively increasing number of coats of paint, it has been found that this is true; the factor A varies from one metal surface to another while the factor P/film-thickness remains constant.—J. P. S.

Investigations of the Absorption Properties of Paints and the Process of Heating when Drying by Radiation. C. A. Landfermann. (Metalloberfläche, 1949, vol. 3, June, pp. A126–A130). The permeability of certain resin paints, glycerine-glyptal, and stoved enamel to infra-red rays was investigated. The impermeability depends on absorption at the surface and is independent of the wavelength; thus in this respect, it is not important whether the radiating element is heated by gas or electricity. With fairly transparent coatings the wavelength is important and the longer wavelengths are more efficient. The reflectivity of the material to which the coating is applied is also important.—R. A. R.

POWDER METALLURGY

Design in Powder Metallurgy. H. W. Greenwood. (Metallurgia, 1949, vol. 40, Sept., pp. 255–256). Reasons are given why some parts made by powder metallurgy have not been satisfactory; this is frequently due to lack of understanding of design limitations. Three fundamental limitations are explained, namely, the lack of plastic flow in metal powders when under pressure, the friction between the metal powder and the die walls and punch or punches, and the limitations imposed by tools and dies. The influence of progress in powder metallurgy upon the design of parts is perceptible and is growing; some examples of this are given.—R. A. R.

Structural Parts from Metal Powders. H. R. Clauser. (Materials and Methods, 1949, vol. 30, Sept., pp. 86–92). The properties of some iron-base powders are listed and the advantages and limitations of the powder-metallurgy process are discussed with recommendations on the designs of dies.—R. A. R.

Ceramics—Silicon Ceramics—Metal Ceramics. Manufacture of Metallic Bodies by Ceramic Methods. Metallic-Ceramic Materials. M. Hauser. (Bulletin de l'Association Suisse des Electriciens, 1949, vol. 40, No. 8, pp. 208–215: American Ceramic Abstracts, 1949, Sept., p. 219). The entirely different properties of metals and ceramic materials are discussed and exemplified by those of cast iron and porcelain, which are, respectively, density 7·876 and 2·3 to 2·5 g./sq. cm., compressive strength 6000 to 9000 and 4000 to 5500 kg./sq. cm., tensile strength 2200 and 240 to 320 kg./sq. cm., coefficient of thermal expansion $12{\cdot}3 \times 10^{-6}$ and 3 to 4×10^{-6}, and thermal conductivity 58 and 0·9 kg.cal./m./hr./° C. The particular methods for manufacturing objects of silicon alloys are described; ceramic bodies contain 65 to 70% silicon. Powdered metals and mixtures of them with ceramic materials are sintered after having been shaped by ceramic methods. Chemical reactions taking place in drying and sintering are explained. A brief history of the development of the use of powdered metals in ceramic bodies is given; first mention was apparently made in 1897–98. Thirteen references are included.

PROPERTIES AND TESTS

Machine for Testing Materials in a Condition of Complex Stress. M. L. Bernshtein, N. M. Onchukov, and I. A. Yarov. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1136–1138). [In Russian]. A machine is described in which a specimen about 200 mm. long can be tested under a combination of tensile and bending stresses at either room or high temperatures.—S. K.

Reconstruction of Old Types of Amsler Testing Machines. N. N. Aistov. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1139–1140). [In Russian]. A device is described for improving the control of the counter-weight in the older types of vertical Amsler testing machines.—S. K.

On the Method of Constructing Diagrams of True Stress. K. K. Likharev. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1343–1347). [In Russian]. The causes of errors in diagrams of true stress recorded with many types of testing machine are considered, and a method of correction is suggested. This method is based on the assumption of direct proportionality between the magnitude of the load on the specimen and the magnitudes of the displacements, due to deformations in parts of the mechanical system, recorded in the diagram. The relationships between the characteristics of a material in tension and in compression are considered, and a design of specimen satisfactory for compression tests is described.—S. K.

Hydraulic Dynamometers. I. A. Obzhirov. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1266–1268). [In Russian]. Various designs of hydraulic dynamometer are considered and some types which have given satisfactory service in practice are described.—S. K.

Measurement of Bending under Small Loads at the Moment of Structural Transformations in Steel. N. E. Karskii and T. I. Sobolev. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1355–1358). [In Russian]. An apparatus is described for the study of the bending, under small constant loads and at high temperatures, of steel specimens 80 mm. long and 4–6 mm. in dia. Results obtained with specimens of two steels containing approximately equal concentrations of chromium, molybdenum, nickel, silicon and manganese, one with 0·12% and the other with 0·74% of carbon, are given. Great increases in plastic deformation were found to accompany the austenite transformation and other processes associated with the heat-treatment of steels involving increased atomic mobility.—S. K.

Plastic Bending. L. A. Shofman and P. I. Lokotosh. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1348–1355). [In Russian]. The processes of plastic bending in the cold and at high temperatures are considered, and a single equation is proposed by which the bending moment can be calculated in both these cases for large deformations. Experimental data taken from indicator diagrams relating to steel specimens at temperatures of 0° to 1300° C. are shown to be in good agreement with those calculated, and the possibility of satisfactorily determining the tensile strength of a material by bend tests is demonstrated.—S. K.

Deformation during Plastic Bending. I. P. Renne. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1359–1364). [In Russian]. The approximations in the equations proposed by V. P. Romanovskii are shown theoretically to make these equations inaccurate for large curvatures in plastic bending. A theoretical study is made of the stresses and deformations in the different layers of the specimen during plastic bending without hardening, equations and diagrams being given to show the distribution in the specimen of deformation and of radial and tangential stresses. The relation of deformation to the dimensions of the specimen and to the coefficient of hardening in those cases in which deformation is accompanied by hardening is also considered.

Ductile Rupturing by Shearing Action in Compression. S. I. Gubkin, A. N. Danilchenko and V. G. Osipov. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1100–1101). [In Russian]. The process of disruption under compression of cylindrical steel specimens is briefly discussed on the basis of experiments carried out at temperatures from 20° to 1300° C.; the types of fracture obtained are illustrated.—S. K.

The Influence of Diffusion Annealing on the Transverse Mechanical Properties of Constructional Steels. H. Krainer and K. Swoboda. (Verein Deutscher Eisenhüttenleute, 1944, Confidential Report No. 63). Tests on low-alloy constructional steels (mainly with C 0·5%, Cr 1·5–2%, and V 0·1–0·2%), on the influence of diffusion annealing on the yield point, tensile strength, elongation, reduction of area, notch-bar strength, internal pressure bursting tests, primary and secondary structure, and microhardness are reported. The diffusion annealing gave variable results. The economic advantages of the use of high forging temperatures and slow heating were stressed.—G. W. A.

Effect of Plastic Strain and Heat Treatment. C. J. Osborn, A. F. Scotchbrook, R. D. Stout, and B. G. Johnston. (Welding Journal, 1949, vol. 28, Aug., pp. 337-s–353-s). This is the third of a series of reports describing the work done at Lehigh University for the Fabrication Division of the Pressure Vessel Research Committee of the Welding Research Council (*see* Journ. I. and S.I., 1949, vol. 162, June, p. 241 and vol. 163, Dec., p. 474). It deals with the effect of fabrication processes on steels used in pressure vessels; the Lehigh slow notched bend test has been used to study the effects of homogeneous cold work and of uniform heat-treatment on cold-worked materials; standard V-notch Charpy tests have also been used, and standard tensile tests were carried on concurrently with the notched tests. Conclusions were that tensile pre-strains of 1% in the rolling direction or transverse to it did not affect the tensile properties of the steels seriously, but in the case of a rimming steel they raised the transition temperature sharply, and to a level not greatly exceeded by greater pre-strain; with an aluminium-killed steel the transition temperature was consistently raised by increasing tensile pre-strains. For pre-strains above 1%, both yield strength and maximum strength increased with increased magnitude of pre-strain. Compressive pre-strain caused a marked decrease in tensile yield point. Strain-ageing tendencies were similar in both rimming and killed steels. The only heat-treatment that consistently restored the ductility and transition temperatures of cold-worked plate was normalizing at 1600° F. (870° C).—J. P. S.

A Torsion Testing Machine of 2,000,000 Inch-Pound Capacity. F. K. Chang, K. E. Knudsen, and B. G. Johnston. (ASTM Bulletin, 1949, Sept., pp. 49–52). An illustrated description is given of a torsion testing machine of 2,000,000 in.lb. capacity which can test specimens up to 4 ft. 4 in. in

dia., 16 ft. long, and can apply twists through any desired angle. The torque is applied by turning an 88-in. dia. rotating head by means of a 4 × ½ in. flat wire rope, using an old model standard Riehle testing machine as the power source. Aluminium torque tubes mounted on SR-4 gauges are inserted at one end of the stationary head, to measure the applied torque accurately. They are of various ranges to give desired sensitivity. The head rests on rollers which permit longitudinal movement when the specimen shortens during the twisting.—J. C. R.

The Influence of the Technique of Preparation of the Notch on the Characteristic of Toughness. S. K. Maksimov. (Zavodskaya Laboratoriya, 1949, vol. 15, Aug., pp. 967–971). [In Russian]. Experiments are described which were carried out to find the influence on the toughness of notched carbon-steel impact specimens of the way in which the notching was carried out. Specimens notched by drilling had the greatest toughness and those notched with a cutter the least, whilst the toughness of specimens notched by abrasive methods was intermediate. It was found, however, that the influence of the method of notch preparation did not exceed the errors of measurement in industrial conditions.—S. K.

The Influence of the Microstructure below the Notch on the Toughness of the Section under Test. A. E. Asnis and B. I. Medovar. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1102–1103). [In Russian]. An account is given of experiments carried out at room temperature and at − 70° C. on test-pieces cut out from the butt-welded portions of weldability specimens consisting of 18-mm. thick low-carbon steel plated with 4 mm. of stainless steel. The toughness of the specimens, notched in various ways, was found to depend almost entirely on the microstructure of the material under the base of the notch.—S. K.

On the Isotropy of Rolled Steel in Relation to Its Tendency to Brittle Failure. L. A. Glikman and E. M. Shevandin. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1218–1228). [In Russian]. An account is given of two series of experiments in which toughness tests were carried out at temperatures ranging from − 180° to + 300° C. on specimens cut with their axes parallel or perpendicular to the direction of rolling. In the first series, a carbon steel and a chromium–molybdenum steel, which had been subjected to different heat-treatments, were used, three systems of notching being employed. In the second series, six steels subjected to the same heat-treatment were used. One conclusion is that the tendency to cold-brittleness of a material, as determined by the position of the critical interval of brittleness, does not depend on the direction of the axis of the specimen in relation to the direction of rolling.—S. K.

Investigation of Square Sub-Sized V-Notched Charpy Specimens. D. C. Buffum. (ASTM Bulletin, 1949, Sept., pp. 45–47). Impact data over a range of temperatures are presented for the standard and for several sub-sized, square, V-notched Charpy specimens of one steel (SAE 3140) which has been given a single heat-treatment. The effects of a reduction in cross-sectional area and small changes in the notch upon the temperature of transition from ductile to brittle fracture are shown. The following conclusions are drawn: (1) Irrespective of size of specimen, the most uniform transition temperature is the lowest temperature at which the specimen breaks with a completely fibrous fracture, as taken from the curve of percentage fibrous fracture *versus* testing temperature; (2) the transition temperature is decreased by reducing the cross-sectional area of the specimen; (3) the effect of small changes in the notch radius is negligible; (4) the shallow notch increases the impact energy by increasing the area under the notch, the transition temperature, however, is lowered; (5) when the size of the specimen has to be reduced, it is advantageous to use as large a sub-sized specimen as possible with a standard V-notch; and (6) the impact energy values obtained from breaking sub-sized specimens on a small machine were in good agreement with those values obtained from breaking similar specimens on a standard machine.

The Determination of Static and Dynamic Yield Stresses, Using a Steel Ball. R. M. Davies. (Proceedings of the Royal Society, 1949, vol. 197, Series A, June 22, pp. 416–432). The static yield stress of a material in plate form may be determined by pressing a steel ball against it till the first appearance of an indentation is observed, and the dynamic yield stress by finding the least normal impact velocity of a steel ball dropped upon it which gives a similar indentation. By the use of either the Guest-Mohr principal stress difference, or the von Mises shear strain energy hypothesis, and with an analysis of the stresses in the plate, the appropriate yield stress can be calculated. From tests on mild-steel armour plate and a nickel–chromium ball-bearing steel it has been found that the ratio of dynamic to static yield stress increases as the hardness decreases, being unity for the nickel–chromium steel, 1·1 for the armour plate, and 2 for the mild steel. The actual values differ from those obtained in tensile and compression tests, due in part to the inaccuracy of the criteria of plastic flow, in part to the difference in work-hardening in the two types of tests, and in part to surface changes caused by polishing. The ratio of the two stress limits is not affected, however, as the stress distributions on the material are identical in both the static and dynamic tests.—J. P. S.

Dynamic *vs.* Static Properties of Low-Alloy Cast Steels. W. K. Bock. (Foundry, 1949, vol. 77, Sept., pp. 72–74, 214–216, 219). The author describes experimental work to determine to what extent impact values vary for given static properties and shows that, irrespective of composition, the impact value is related to both tensile strength and reduction of area. For quenched and tempered steels the relation which produces the best relationship is the plane: $C = 6{\cdot}234 - 0{\cdot}310T + 0{\cdot}540R$ (where C = Charpy value in foot-pounds, T = tensile strength in 10,000 lb. sq. in., R = % reduction in area), with a standard error of estimate of 3·99 ft.lb. Normalized and tempered steels give the equation $C = 40{\cdot}125 - 2{\cdot}696T + 0{\cdot}188R$, with a standard error of estimate of 2·85 ft.lb. The possible effects of composition are discussed and it is suggested that if composition is adjusted to produce given tensile strength and reduction of area for a given type of heat-treatment, the Charpy value will be determined by the tensile properties and not by the analysis.—J. C. R.

Free Machining Steels—A Report on Ductility and Impact Resistance. W. L. Williams. (Journal of the American Society of Naval Engineers, 1949, vol. 61, Aug., pp. 543–553). An investigation to compare the ductility and impact strength when stressed in the direction of rolling, of free-machining steels with those of ordinary carbon steels is reported. Within the hardness range usually encountered there was no significant difference in tensile strength, for equal hardness, between the two classes of steel. In general, the free-machining steels had slightly less ductility than those of non-free-machining steels of equal hardness for the hot-rolled, annealed, and quenched and tempered conditions, but this difference was not observed for the cold-rolled condition. The higher the sulphur the lower, in general, was the transition temperature from ductile to brittle fracture in impact tests: the quenched and tempered steels have the lowest transition temperature. R. A. R.

Impact Testing at High Velocities, Some Testing Machines and Results. G. Hansen. (Dansk Teknisk Tidsskrift, 1949, vol. 73, Aug., pp. 223–226; Oct., pp. 288–292). [In Danish]. Results in some recently published reports on impact testing at high velocities are critically reviewed with special reference to the work of P. E. Dowez and D. S. Clark and of M. P. White and L. Griffis (*see* Journ. I. and S.I., 1947, vol. 157 Sept., p. 152, and 1949, vol. 161, Jan., p. 72).—R. A. R.

Graphical Analysis of Impact of Bars Stressed Above the Elastic Range. K. J. DeJuhasz. (Journal of the Franklin Institute, 1949, vol. 248, July, pp. 15–48; Aug., pp. 113–153). A number of impact problems of engineering interest are analysed by a graphical method previously developed by the author. These problems comprise: (1) Impact at constant velocity of finite duration applied to (*a*) one end of a bar of infinite length, (*b*) bars of finite length, the other end being free, (*c*) bars of finite length with the other end fixed or restrained; (2) impact stresses below the yield stress; and (3) impact stresses above the yield stress. The energy expended in impact, and its distribution into energy of plastic deformation, residual kinetic stress energy, and elastic stress energy are determined.—R. A. R.

Cold Work Hardening and Recovery of Low-Carbon Steel Strip Having Regard to the Metallurgically Controlled Characteristics of the Material. G. Niebch and J. Brockhaas. (Max-Planck-Institut für Eisenforschung: Archiv für das Eisenhüttenwesen, 1949, vol. 20, Sept.–Oct., pp. 329–336). The increase in strength on cold rolling and the subsequent decrease on tempering in the 350–600° C. range were studied

using specimens of 1-mm. thick low-carbon steel strip produced by the open-hearth, basic-Bessemer, and other blowing processes. The increase in strength was the same for open-hearth and aluminium-killed blown steel; there was little difference in reduction in elongation which accompanied this increase. The reduction in strength on annealing depended for the most part on the values obtained in the cold-rolled state. If the cold rolling and annealing temperature normally applied to open-hearth steel were applied to strip of steel made by other processes, very considerable differences in tensile strength were observed with, in some cases, unsatisfactory elongation. If, however, the degree of cold deformation and the annealing temperature are adjusted to suit the material, it is possible to obtain properties in other steels equal to those of the open-hearth steels.—R. A. R.

Strain-Age-Hardening. C. A. Edwards. (Iron and Steel, 1949, vol. 22, July, pp. 365–368; Aug., pp. 401–404; Sept., pp. 439–440). A review is presented of research work that has been carried out on the subject of strain-age-hardening and results obtained are discussed. In the last part the effects of oxygen, carbon, nitrogen, titanium, and aluminium on strain embrittlement are summarized.—J. C. R.

Accurate Determination of the Residual Stresses in Surface-Compressed Round Bars. O. Föppl. (Schweizer Archiv, 1949, vol. 15, Aug., pp. 242–248).

The Dislocation Theory of Slip. F. R. N. Nabarro. (Metallurgia, 1949, vol. 40, Aug., pp. 199–205). The three main developments in Great Britain of the dislocation theory of slip during recent years have been the attempt to derive a theory of slip on an atomic basis by Mott and others in Bristol; the study of the bubble model by Bragg, Nye, and Lomer in Cambridge, and the investigation of the interaction between dislocations and dissolved atoms by Cottrell and his collaborators in Birmingham (*see* Journ. I. and S.I., 1948, vol. 160, Dec., p. 444). These theories are reviewed and discussed.

R. A. R.

A Magnetic Strain Gage for Static Metallic Members. J. G. Gable. (Product Engineering, 1949, vol. 20, Nov., pp. 119–120). The magnetic strain gauge described may be used on crane jibs to give a signal when the safe loading limit is reached. Two variable reactors with an armature between them are enclosed in a housing from which a pilot bar integral with the armature extends at one end. The assembly is attached at three points to the jib so that the air gaps on each side of the armature are approximately equal at no load. Strain in the jib is transmitted by the pilot bar, moves the armature, and increases the impedance of one reactor while decreasing that of the other. This difference is transmitted via a matching potentiometer, a high-impedance voltmeter, and a relay to a controller placed at any desired position.—R. A. R.

Wire Resistance Strain Gauges. T. B. Sansom. (Mechanical World, 1949, vol. 126, July 29, pp. 113–117). Circuits and instruments used for controlling electrical resistance strain gauges are described.—R. A. R.

The Physical Characteristics of Wire Resistance Strain Gauges. E. Jones and K. R. Maslen. (Royal Aircraft Establishment, Report Instn. 2, Nov. 1948: [Abstract] Journal of The British Shipbuilding Research Association, 1949, vol. 4, Oct., p. 472).

The Geometry of Plastic Deformation. E. Schmid. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1949, vol. 94, Aug.–Sept., pp. 267–274). An attempt is made to demonstrate the fundamental geometric and physical aspects of the plastic deformation of crystals. The Becker-Orowan theory can only be explained by discussing the dependency of the critical shear stress on temperature. A realization that shear stresses equal to the lattice shear strength do arise in the small zones of the translation surfaces is necessary for an understanding of this theory.—R. A. R.

The Atomic Aspects of Plastic Deformation. G. Masing. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1949, vol. 94, Aug.–Sept., pp. 274–282). The basic problems connected with deformation velocities and forces in the translation of crystals and parts of crystals are critically examined.—R. A. R.

The Structural Theory of the Phenomena of Elasticity and Plasticity in Metals. J. Goujou. (Publications de l'Association des Ingénieurs de la Faculté Polytechnique de Mons, 1949, vol. 97, No. 2, pp. 17–29). A review is presented of the work of various investigators on elasticity and plasticity phenomena in metals.—J. C. R.

On the Conditions in which Semi-Brittle Fractures Occur. H. de Leiris. (Association Technique Maritime et Aéronautique, June, 1949: [Abstract] Journal of The British Shipbuilding Research Association, 1949, vol. 4, July, p. 318). The author discusses the conditions for the occurrence of semi-brittle fractures and shows experimentally that in order to reproduce them in the laboratory without resorting to the artifice of lowering the temperature, it is necessary to use test-pieces which are not only notched, but which are also capable of storing up, in an elastic form, sufficient energy to maintain the progress of the crack, which travels at a high speed, hence arises the conception that a minimum length is necessary for these test-pieces. It can easily be understood, therefore, why in actual structures it is those with the largest absolute dimensions that furnish the greatest number of examples of semi-brittle cracks. From this point of view ships, particularly ships of simple structure, such as cargo ships or tankers of high tonnage, represent critical cases. The author shows that, even under hydraulic pressure, the testing of large pressure vessels capable of accumulating an appreciable store of energy by elastic deformation of the shell entails a risk which should not be underestimated.

Transition Temperatures of Ducol W.27 and Heat Treated D.W. Steels. (Admiralty Engineering Department, H.M. Dockyard, Portsmouth, Central Metallurgical Laboratory. Metallurgical Report DNG, ACSIL/ADM/49/570: [Abstract] Journal of The British Shipbuilding Research Association, 1949, vol. 4, Oct., p. 455). The results are given of the determination of the transition temperature for Ducol W.27 and heat-treated D.W. steel in the as-received, strain-aged, and quench-aged conditions. Both steels are shown to have low transition temperatures in the as-received condition, which are raised by straining and ageing. Ducol W.27 is unaffected by quench-ageing but the heat-treated D.W. steel is adversely affected. The significance of the quench-ageing of heat-treated D.W. steel and its practical implications in welding are discussed.

Relationships between the Various Characteristics of Deformation. V. G. Osipov. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1339–1342). [In Russian]. Some expressions in use for the quantitative representation of deformation are enumerated and discussed, special attention being given to six characteristics in terms of elongation and displacement. It is shown that a well-defined connection exists between these characteristics of deformation. A series of relationships is given by which the mutual conversion of the characteristics can be carried out, together with a possible simplification for dealing with the complicated expressions encountered in conversions involving octahedral displacement.—S. K.

Tessellated Stresses—Part V. F. László. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 5–26). Continuation of a series of papers (*see* Journ. I. and S.I., 1945, No. II, p. 207P). The currently accepted theory of the influence of strains due to volume change on the shape of precipitates is carefully examined but rejected. The rules giving the true shaping effort of these strains, in terms of the elastic constants, and the yield stress of matrix and precipitate, are determined. Experimental observations with ferrous and non-ferrous metals are reviewed in the light of the new theory. The conventional views on dislocation are extended by the idea that the atomic structure must become buckled. This leads to suggestions as regards the interpretation of hardness phenomena. Some special questions discussed in previous parts are reconsidered and explained in greater detail.

Experimental Method for Lamellar Similarity. I. M. Ass. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1104–1107). [In Russian]. Equations relating to similarity principles are deduced for the study of various types of deformation in plate specimens, and a device for the experimental application of these principles is described.—S. K.

On the Method of Determining Residual Stresses Caused by Shot-Peening. L. M. Shkolnik. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1232–1239). [In Russian]. Experiments are described in which prismatic specimens of different steels, 15 × 15 × 120 mm., were shot-peened under various conditions. The distribution of residual stress was then determined by removing successive thin layers from the specimen by treatment with nitric acid and determining the change in the curvature of the specimen taking place at each

removal. The influence of the size of the shot, of the hardness of the steel and of the specimen thickness on the results of shot-peening are discussed on the basis of the results obtained, and the nature of the fractures occurring in shot-peened and untreated gear teeth are compared.—S. K.

Experiments in the Use of the Pulsator for the Endurance Testing of Gear Teeth. R. S. Nikolaev and L. M. Shkolnik. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1264–1265). [In Russian]. An account is given of the use of a pulsating device for the endurance testing of gear teeth, the relation between the dimensions of the teeth and of the plunger for conditions most closely similar to those of operation being considered.—S. K.

Effect of Chromium Plating on the Endurance Limit of Steels Used in Aircraft. H. L. Logan. (Journal of Research of the National Bureau of Standards, 1949, vol. 43, Aug., pp. 101–112). It was found by rotating-beam fatigue tests that chromium plating reduced the endurance limits of specimens of chromium–molybdenum and chromium–vanadium steels. The endurance limits for steel of a given hardness decreased with increasing plating-bath temperature. This detrimental effect of chromium plating is attributed to stresses in the chromium and/or the steel, which are increased by low-temperature baking (up to 350° C.), but are partly relieved by baking at 400° to 440° C.—R. A. R.

On the Calculation of Hardness. V. K. Grigorovich. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1088–1094). [In Russian]. From a consideration of the hardness testing of steels and non-ferrous metals of differing hardness with spherical, conical, and pyramidal indenters, it is concluded that the calculation of hardness from the area of the projection of the impression is simpler than from that of its surface. The use of the area of the projection simplifies the application of corrections made necessary by any distortion of the impression.—S. K.

Development of the Jominy End-Quench Test for Steel of Small Dimensions. H. Schrader. (Werkstatt und Betrieb, 1949, vol. 82, Sept., pp. 329–334). The suitability of the Jominy end-quench test for various steels is discussed. It is considered very useful for alloy steel tools and case-hardening steels but not for plain carbon tool steels. A modification of the test suitable for small specimens down to 3 mm. in dia. is described.—R. A. R.

Micro-Hardness Testing. H. A. Unckel. (Metal Industry, 1949, vol. 75, Nov. 18, pp. 431–432). A microhardness tester designed to meet two requirements is described. It had to be of simple construction with sufficient accuracy, and capable of being used with microscopes of the table type and of the inverted type. In this instrument the load is applied by a lever carrying an adjustable weight to a steel ball in the back of the diamond holder. To ensure true vertical movement of the diamond, the diamond holder is a well-polished cylinder sliding in a polished and lubricated tubular member. The device is inserted in place of the microscope's objective.

Investigation of the Cold Brittleness of Steel from the Parameters of a Conical Indentation. F. S. Savitskii, I. A. Zakharov, and B. A. Vandyshev. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1095–1099). [In Russian]. Dynamic and static tests with a conical indenter on specimens of steels and some non-ferrous metals are described. Many of these tests were carried out on steel in the temperature range − 196° to + 500° C., and relationships are traced between temperature, hardness, the nature of the deformed region round the indentation, the indentation, and the speed of indenting. On this basis the critical temperature of brittleness for the steel and its dependence on speed of indentation in the range 0·5–9 m./sec. is calculated.—S. K.

Method of Hardness Testing at High Temperatures. I. L. Mirkin and D. E. Livshits. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1080–1087). [In Russian]. An account is given of a simple and reliable method of hardness testing at temperatures above 600° C., in which a metallic-ceramic indenter protected from oxidation by a special thermal diffusion treatment, is used. The method was used for the investigation of the hardness at temperatures up to 700–800° C. of pure iron, nickel, cobalt, chromium, molybdenum, and tungsten, and of high-temperature alloys based on nickel–chromium–iron, nickel–iron–cobalt, and cobalt–chromium. High-temperature hardness was found to be a good index of the influence of ageing and of alloying elements on the behaviour of alloys at high temperatures.—S. K.

Carbide Distribution as a Possible Cause of Temper Brittleness. L. D. Jaffe. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 1–3). The difficulties of reconciling current theories of temper brittleness of steel with the experimental data are pointed out. A new hypothesis is suggested: that temper brittleness may arise from the effect of temperature, in the sub-critical range, upon the quasi-equilibrium distribution of carbides or other phases. This hypothesis is examined theoretically, and it is found that the interfacial energy between ferrite and the phases mentioned would have to be approximately half the interfacial energy between grains of ferrite. Consequently, if the hypothesis is valid, the phase responsible for temper brittleness cannot be cementite.

Magnetic Characteristics of an Oriented 50 Percent Nickel–Iron Alloy. J. H. Crede and J. P. Martin. (Journal of Applied Physics, 1949, vol. 20, Oct., pp. 966–971). Single crystal magnetic properties have been closely approached in a polycrystalline 50/50 nickel–iron alloy by developing a favourable grain orientation. The method is adapted to commercial production by careful control of processes affecting the fundamental magnetization process in the magnetic domain. Elimination of steps I and III of the normal magnetization has produced an almost geometrically true rectangular shape of the hysteresis loop.

Magnetic Properties of Cast Stainless Steel. E. A. Schoefer. (Alloy Casting Bulletin, 1949, Aug., pp. 1–4, 6). The differences between the cast and wrought stainless steels of the American types 304 and 316 (wrought) and CF-8 and CF-8M (cast) are pointed out. Rolling demands an austenitic structure, whilst casting demands good fluidity. Since the low-carbon alloys are quite viscous, the fluidity is obtained by increasing the silicon which is less detrimental to the resistance to nitric acid than an increase in the carbon. To compensate for the added silicon, the chromium is increased and the two together cause the cast alloy to become partially ferritic. If corrosion resistance were less important than the magnetic properties, there would be no difficulty in producing non-magnetic castings by raising the nickel content.—R. A. R.

Minor Hysteresis Loops of Permanent Magnet Materials Obtained by Incomplete Saturation. W. Jellinghaus. (Zeitschrift für Metallkunde, 1949, vol. 40, Sept., pp. 339–344). A series of minor hysteresis loops (*i.e.*, loops obtained when the magnetic intensity is reversed before the maximum value is reached) for a number of permanent magnet materials are constructed, commencing from the demagnetized state. The series gives a fairly uniform picture when the magnetization curves are derived using the coercive force from the major loop as the unit of field strength and the magnetic intensity at saturation. With field strengths up to 30% of the coercive force, a flat Rayleigh loop with small hysteresis and a permeability of the order

$$\frac{0{\cdot}15 \times 4\pi I \varkappa}{H_c}$$

are obtained.

With greater field strengths the hysteresis and the slope of the minor curves increase. With field strengths equal to and greater than the coercive force the curves change from the Rayleigh to the well known **S** type. With anisotropic materials with preferred magnetic orientation this change is almost sudden. A material with a rolled texture is superior to anisotropic material as regards induction, remanence, and hysteresis loss. The maximum magnetization reaches about 90% saturation with a field strength equal to four times the coercive force. The hysteresis loss of isotropic permanent magnet materials follows the Steinmetz law $A = \eta \times B^{\alpha}$. The exponent α has a value of about 2·2.—R. A. R.

Inspection Methods of New and Used Oil Country Tubular Goods. M. W. Newman. (Non Destructive Testing, 1949, vol. 8, Summer Issue, pp. 9–13). The Tuboscope, Magnaflux, and Magnaglo methods for inspecting the internal surfaces of pipelines are described. The Tuboscope consists of a system of lenses set in tubes; a light source, consisting of a mercury vapour lamp, and an angle mirror are located at the front end of the instrument, and a focusing eye-piece is at the rear end. A wide-angle objective lens at the front end makes it possible to see down the pipe for a distance of 9 in. at a time, and simultaneously shows the entire internal surface for that distance. A supplementary angle mirror located at the centre of the image, just behind the light source, gives a perpendicular image of a small area of the pipe. Some results obtained with this instrument are shown.—R. A. R.

Oil Tool Manufacturing and Non-Destructive Testing. F. R. Drahos. (Non-Destructive Testing, 1949, vol. 8, Summer Issue, pp. 33–35). The use of Magnaflux, radiography, and electrical resistance strain gauges for testing oil-well equipment is described.—R. A. R.

The Part Played by Crystal Boundaries in the Anomalies in the Propagation of Ultrasonic Waves in Metals. P. Bastien, J. Bleton, and E. de Kerversau. (Comptes Rendus, 1949, vol. 229, Nov. 14, pp. 1016–1018). When soundings are made by the reflection of ultrasonic waves anomalies of reflection and transmission appear in the form of a certain number of parasitic echoes of variable amplitude, very mobile when the probe heads are moved even very slightly at the surface of the specimen, and the basic echo cannot be observed. They appear when the microstructure of the cold metal contains an element the dimensions of which are equal to or a multiple of half the wavelength of the ultrasonic wavelength used ; in the simple cases so far studied this structural element may be the crystal of metal or of solid solution in homogeneous media or the complex structure bounded by the pro-eutectoid ferrite and the vestige of the gamma grain at raised temperatures in ordinary or low-alloy steels cooled slowly. The suggestion that grain boundaries have the appearance of an envelope the elastic properties of which differ sharply from those of the mass of the crystals appears to fit the facts ; on this basis calculation shows that resonance (which causes the crystal structure to behave as a source of ultrasonic waves and so produce the anomalies) can occur only if the crystals have dimensions of not less than half the wavelength.—A. E. C.

Dismountable Ionic X-Ray Tube for Structural Analysis. V. G. Prokhvatilov and E. I. Gindin. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1071–1074). [In Russian] A design of X-ray tube which is flexible in operation and can easily be stripped and reassembled is described.—S. K.

New Developments in the X-Ray Testing of Materials. H. Gombel. (Metallwirtschaft, 1949, vol. 3, Sept., pp. 296–299). The single-pole hollow-anode and the single-pole fine-focusing X-ray tubes are described and illustrated.

R. A. R.

How Pennsylvania Railroad Uses X-Ray Inspection. D. Goodman. (Iron Age, 1949, vol. 164, Sept. 1, pp. 80–83). The fixed and mobile X-ray equipment used by the Pennsylvania Railroad is described. It is applied for the examination of new and replacement parts in equipment, for the inspection of used parts, and to assist the purchasing department.—J. P. S.

An Automatic Timer for Radioactivity Measurements. B. D. Corbett and A. J. Honour. (Electronic Engineering, 1949, vol. 21, Sept., pp. 341–345). In research work involving radio-active isotopes and Geiger counters it may be necessary to detect pulses of a few volts amplitude and 100 microseconds duration and to determine the counting rate over a range of 10/min. up to several thousand pulses/sec. An apparatus is described for carrying out this timing operation automatically in conjunction with one of the commercially available electronic scalers.—R. A. R.

X-Ray Camera for Photographing the Reciprocal Lattice. Iu. A. Bagaryatskii and M. M. Umanskii. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1320–1328). [In Russian]. After a discussion of various X-ray methods available for photographing the reciprocal lattice, the construction of a camera for this purpose is described in which synchronized rotation of the goniometric head and adapter is arranged.—S. K.

Influence of Strain Rate and Temperature on the Creep of Cold-Drawn Ingot Iron. W. D. Jenkins and T. G. Digges. (Journal of Research of the National Bureau of Standards, 1949, vol. 43, Aug., pp. 117–125). A study was made of the effects of variations in strain rate and temperature on the creep characteristics in tension of cold-drawn ingot iron. The third stage of creep began without necking or without the presence of cracks of microscopic dimensions, but considerable necking occurred in all specimens tested to fracture. The stress required to initiate fracture also increased as the strain rate increased. The general trend was that ductility at fracture increased with an increase in the strain rate and plastic extension at fracture decreased with a rise in temperature.—R. A. R.

The Overheating and Burning of Steel. Part III—The Influence of Excessive Reheating Temperatures on the Mechanical Properties and the Structure of Alloy Steel. A. Preece, J. Nutting, and A. Hartley. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 37–45). The investigations reported are an extension of earlier work on the overheating of steel (*see* Journ. I. and S.I., 1946, No. I, pp. 217P–317P). Mechanical tests have been used to follow the changes induced in a range of alloy steels after treatment at temperatures up to 1425° C. A survey has been made of the influence of cooling rate on the development of the overheated condition. A statistical examination of the effect of steel composition upon overheating temperature has indicated that carbon and sulphur are important constituents, but the influence of oxygen is doubtful. A number of related problems, such as austenite grain growth within the range of overheating temperatures and the influence of overheating on the isothermal decomposition of austenite, have also been investigated. The conclusions drawn are that overheating is a result of some change in composition at the boundaries of the austenite grains existing at the high temperature. Burning occurs as a result of partial melting and a subsequent segregation of phosphorus, accompanied by the precipitation of sulphides from the molten metal.

An Introduction to Gases in Steel. D. J. Carney, J. Chipman, and N. Grant. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 34–45). The paper is in three parts. In the first, apparatus for determining the solubility of gases in metals is described, and results, which show the effect of temperature, pressure, state of the metal, and alloying elements, are presented. In the second, the effect of water vapour on the solubility of hydrogen in steel is dealt with. Thermodynamic considerations reveal that when steel is nitrided with ammonia the iron may be 'hydrided' with water vapour. The third part is concerned with the effect of hydrogen on the physical properties. In most cases hydrogen is an undesirable element in steel. In measuring hydrogen embrittlement, the rate of strain is a very important factor.

Gases in Steel. E. W. Pierce. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 45–46). Moisture in the charge and additions to electric furnace heats have little influence on the hydrogen in the bath during the oxidizing period, but they increase the hydrogen during the reducing period. The hydrogen content of the finished molten steel increased with the humidity of the atmosphere until the introduction of the injection of oxygen as standard practice ; this reduced the hydrogen content to a low and consistent value, even when the humidity varied over a wide range.—R. A. R.

Some Observations on Gases in Steel. C. E. Sims. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 46–52). Curves are presented showing the decrease in hydrogen content and improvement in ductility of steel with ageing at room and at elevated temperatures. With 4-in. specimens, ageing at 400° F. was 240 times as fast as at room temperature. The evolution of nitrogen and carbon monoxide is also dealt with. It appears that steels, including the killed steels, have gas-forming potentialities that need only slight encouragement to set them in motion. Nitrogen is probably a potent factor in the porosity of freezing steel, and its origin may be the decomposition of newly precipitated unstable nitrides in the freezing zone.—R. A. R.

Gases in Steel. G. Derge. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 53–54). The rates of absorption and evolution of hydrogen from steel and the conditions which accelerate these rates are discussed.—R. A. R.

Kinetics of Gases in Steel. L. S. Darken. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference, Dec., 1948, vol. 6, pp. 55–59). Methods of calculating the rates of fall of the carbon, nitrogen, and hydrogen contents of a steel bath are developed. There is considerable evidence that steel and iron tend to exchange nitrogen and hydrogen rather rapidly with any gaseous atmosphere with which they may come in contact. In the short time taken by the bubbles of the boil to rise through the bath the hydrogen does attain, and the nitrogen nearly attains, equilibrium with the hydrogen and nitrogen of the bath respectively.—R. A. R.

METALLOGRAPHY

Special Microscopes for Metallurgy. V. Ronchi. (Aluminio, 1949, vol. 18, Sept.–Oct., pp. 498–502). [In Italian]. The laws relating to the magnifying and resolving powers of microscopes and the technical reasons which have led to the present design are summarized. The reasons for the lesser use in the past of the reflecting microscope compared with that of the refracting microscope are discussed. Nowadays, however, the reflecting microscope is preferred for the examination of high-temperature metal surfaces which must be examined from a certain distance.—R. F. F.

Theory of Growth of Spherical Precipitates from Solid Solution. C. Zener. (Journal of Applied Physics, 1949, vol. 20, Oct., pp. 950–953). The radius of a spherical precipitate particle growing in a solid solution of initially uniform composition may be shown to be equal to $\alpha(Dt)^{\frac{1}{2}}$, where D is the atomic diffusion coefficient, t the time of growth, and α, the growth coefficient, is a dimensionless function of the pertinent compositions. In this paper the precise dependence of this function upon the pertinent concentrations is found and a similar computation is made for the growth coefficient corresponding to the one-dimensional growth of a plate.

Microscopic Evidence of Orderly Precipitation in Some Fe–Ni–Al Alloys. A. J. Bradley. (Physica, 1949, vol. 15, Apr., Reprint). Investigations with the microscope have yielded interesting examples of orderly precipitation in connection with the formation and decomposition of superlattice structures. The ordered phase may frequently separate out in the form of spheres or cubes, especially with rounded corners. These are probably integral multiples of the mosaic unit of $\frac{1}{4}$ micron, evidently formed by stacking together a number of neighbouring mosaic cells.—R. A. R.

Precipitation from Solid Solutions of C and N in α-Iron. C. A. Wert. (Journal of Applied Physics, 1949, vol. 20, Oct., pp. 943–949). The formation of the solid solutions of carbon and nitrogen in α-iron has been studied by means of the internal friction peak associated with the stress-induced interstitial diffusion of the solute atoms. A transformation law has been found to fit the experimental data. The data are interpreted as showing : (1) Fe_3C precipitates in the shape of spheres ; (2) an intermediate phase in the precipitation of nitrogen forms in the shape of discs ; and (3) within the experimental error no continuous nucleation is indicated.

The Detection of Overheating and Burning in Steel by Microscopical Methods. A. Preece and J. Nutting. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 46–50). A review is given of the etching reagents which have been used to detect overheating and burning in steel. An investigation of the action of an electrolytic ammonium nitrate etch is described and a theory advanced for its differential action with not overheated, overheated, and burnt steel.

Grain-Boundary Phenomena in Severely Heated Steel. T. Ko, and D. Hanson. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 51–62). A study has been made of the structure and tensile properties of carbon steels which have been quench-hardened after being heated to very high temperatures in the austenitic range. A new metallographic method of studying overheating has been used which shows that, on overheating, sulphide inclusions are precipitated at the austenite grain boundaries ; these inclusions cannot be seen in an ordinary microsection. A subsidiary investigation of some specially prepared iron alloys has shown that the presence of manganese sulphide is necessary for the precipitate to occur. Two effects are found when the steel has been heated to temperatures very near the solidus : the sulphides are precipitated at the grain boundaries in the form of a eutectic, and there is a segregation of phosphorus to the precipitated regions. The effect of high austenitizing temperatures on the tensile properties of martensite has been studied on low-carbon steels and on an Fe–C–Mn alloy. Martensitic plain carbon steels containing 0·08, 0·17, and 0·23% of carbon have tensile strengths of 73, 95, and 110 tons/sq. in. respectively, and have reductions in area of 40–50% when fine-grained. The ductility decreases with increasing austenitizing temperature ; in steels heated below the overheating temperature this loss of ductility can be recovered by a single normalizing treatment, but in overheated steels little recovery can be achieved except by subjecting the material to rather elaborate heat-treatment. The theory is put forward that overheating is due to the partial precipitation on the austenite grain boundaries, at high temperatures, of sulphide brought into solution during heating ; the precipitation takes place when cooling, at a suitable rate, to the overheating temperature. Segregation of phosphorus occurs when the solidus/liquidus range of the steel (the solidus being lowered by the presence of sulphur in solution) is entered at very high temperatures.

The Exact Measurement of the Constants of the Crystal Lattice. A. Z. Zhmudskii. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1055–1061). [In Russian]. A modified back-reflection X-ray method of measuring the constants of the crystal lattice of large specimens is described ; it is based on taking two photographs on the same plate with different distances of specimen to plate, these distances being of the order of hundreds of millimetres. The method was tested with specimens of iron and of aluminium and was found to be accurate to 2×10^{-3}% and to be suitable for the determination of the coefficient of linear thermal expansion and for the study of processes associated with small changes of lattice dimensions.—S. K.

Universal Camera for the Determination of Crystalline Structure by the Weissemberg Method. J. M. Torroja, E. P. Diaz, and J. L. Amoros. (Revista de Ciencia Aplicada, 1949, vol. 3, July–Aug., pp. 250–254). [In Spanish]. The defects of the rotating crystal technique for the determination of crystalline structures, have given rise to X-ray crystallographic methods in which the independence of individual reflections is achieved by using a single cone of reflections of the crystal by means of a suitable screen. In the Weissemberg method, the independence of reflections is obtained by the translation of the photographic film co-axially with the axis of rotation of the crystal. The present paper describes an apparatus known as the vertical Torrojo model, built in the Leonardo Torres Quevedo Institute of Scientific Instruments, to obtain diagrams according to all the varieties of the original Weissemberg process. Its general operation is described and the reversing mechanism of the plate-holder is explained.—R. S.

The Nucleation Phenomena in the Transformations of Steels. P. Laurent. (Conservatoire National des Arts et Métiers, Symposium on Metal Physics, Paris, 1948, pp. 5–18). The author discusses the physical mechanism of those transformations in steels which are normally considered as transformations by nucleation. He first summarizes the transformations in pure metals to provide the necessary background for the consideration of the formation of nuclei, the growth of nuclei, the effect of a change of volume, the kinetics of the transformation, nucleation in solid solutions, the formation of austenite, the austenite grain-size, the γ–α transformation, the formation of pearlite, the effect of special elements and of heterogeneity on the austenite decomposition, the formation of bainite, and the influence of special elements on it.—A. E. C.

The Decomposition of Austenite under Isothermal Conditions and the Practical Application of this Reaction for the Treatment of Steels. A. Sourdillon. (Conservatoire National des Arts et Métiers, Symposium on Metal Physics, Paris, 1948, pp. 19–38). The author first presents time/temperature/transformation curves for plain carbon, structural, and alloy steels and then discusses the effects of isothermal heat-treatment in practice on the hardness of the products after partial and after complete isothermal transformation of the austenite. After touching on the bainitic treatment of high-speed steels, the author reviews the mechanical properties produced by various isothermal heat-treatments, refers to the advantages of this heat-treatment process in reducing the extent of deformation and in eliminating quenching cracks, discusses the volume change during the transformation, and concludes with a survey of the isothermal heat-treatments. A bibliography of 42 references is appended.—A. E. C.

Contribution to the Theory of the Martensitic Transformations. C. Crussard. (Conservatoire National des Arts et Métiers, Symposium on Metal Physics, Paris, 1948, pp. 39–53). The author discusses the theory of martensitic transformations in both ferrous and non-ferrous materials under the following headings : I—Generalities (the meaning of the term 'martensitic transformation'). II—Review of the characteristics of some martensitic transformations. III—Mechanism of the martensitic transformation (crystallographic study of martensite in steels and the atomic

movements in its formation, martensitic transformations in other metals, thermodynamic study). IV.—Internal stresses in a quenched metal. V—Particular features of the martensitic transformation (influence of grain-size on the M_s point, thermal arrest, reversibility of the transformation, stabilization above the M_s point and between M_s and M_f). A bibliography of 48 references is appended.—A. E. C.

The Martensitic Quench and Tempering. A Michel. (Conservatoire National des Arts et Métiers, Symposium on Metal Physics, Paris, 1948, pp. 55–66). The author discusses the modality of the martensitic transformation in steels and the influence on it of the composition of the metal, the heating temperature before quenching, the rate of cooling, ageing, and of a partial transformation in the higher ranges; the transformation of residual austenite into martensite; stepped quenching; secondary quenching; quenching cracks; and tempering.—A. E. C.

General Survey on the Decomposition of Austenites. H. Jolivet. (Conservatoire National des Arts et Métiers, Symposium on Metal Physics, Paris, 1948, pp. 67–74). Present-day knowledge of and views on the decomposition of austenite in steel in the three temperature ranges (upper, intermediate, and lower) are summarized, and the application of the results of the study of isothermal decomposition to practical conditions is discussed.—A. E. C.

The Study of Transformations in Austenitic Alloys by the Magnetic Method. G. V. Estulin. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1262–1263). [In Russian]. Experiments are described in which the magnetic susceptibility and saturation of specimens of chromium–nickel and chromium–manganese–tungsten steels were determined after subjection to different hardening temperatures up to 1300° C. and times of ageing at 500°, 600°, 700°, and 800° C. up to 1000 hr. The ferrite contents calculated from the results of the magnetic measurements were found to agree well with those obtained through metallographical analysis for the hardened specimens, but X-ray examination of the aged specimens indicated that their magnetic properties depended not only on the α-phase content, but also on the extent to which this phase had been enriched with chromium during the ageing.—S. K.

A New Intermetallic Phase in Alloy Steels. K. W. Andrews. (Nature, 1949, vol. 164, Dec. 10, p. 1015). A new intermetallic phase has been discovered in alloy steels containing chromium, nickel, and molybdenum, and has been designated 'χ': it does not appear to be an alternative high- or low-temperature form of the σ-phase, though its chemical composition is similar except in its nickel, molybdenum, and silicon contents. Debye-Scherrer powder photographs show it to be similar in structure to α-manganese. The 'χ' phase has so far only been discovered in steels containing molybdenum, and may thus be associated with the presence of this element, and possibly of tungsten.—J. P. S.

X-Ray Line Breadths of Martensite. M. A. Jaswon and J. Mazur. (Nature, 1949, vol. 164, Oct., 22, pp. 712–713). In the first of two letters, Jaswon, referring to a recent note by Mazur (*see* Journ. I. and S.I. 1950, vol. 164, Mar. p. 378) on the connection between X-ray line broadening and grain-size and microstress in martensite at low temperatures, states that Mazur has not mentioned the work of Wheeler and Jaswon (*see* Journ. I. and S.I., 1947, vol. 157, pp. 161–166). There, it was concluded that the line broadening was mainly due to the internal stress. Mazur, in a reply, quotes other workers to show that while the internal stress is the main factor in causing line broadening, the small particle size cannot be entirely neglected.—J. P. S.

Effects of Stress and Deformation on the Martensite Transformation. A. W. McReynolds. (Journal of Applied Physics, 1949, vol. 20, Oct., pp. 896–907). The relation between elastic and plastic strains and the martensite transformation from face-centred to body-centred structure has been investigated in a 71/29 iron–nickel alloy. Transformation begins at about − 30° C. and is of the martensite type, except that it is not all completed instantaneously, but continues at a decreasing rate at constant temperature.—R. A. R.

The Breakdown of Austenite below the M_s Temperature. F. C. Thompson and M. D. Jepson. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 27–35). After demonstrating that there is no reason to doubt that austenite in a plain carbon eutectoid steel can decompose isothermally below the M_s temperature, it is suggested that the decomposition during the actual quenching operation and that due to the isothermal transformation should be considered quite independently, and so shown in the isothermal transformation diagram.

The results of dilatometric investigations show that, so far as the second factor is concerned, decomposition becomes progressively slower as the temperature is lowered, and that there is no sign of a knee in the curve. The nature of the transformation product in this range of temperature is considered, the conclusion reached being that it is martensite in the first instance, which tempers progressively as the time is increased. This leads to an acicular, bainitic product, which is of secondary origin. Determinations of the maximum rate of breakdown, $R_{max.}$ suggest that this is related to the temperature by an equation of the type $R_{max.} = Ke^{k\theta}$. There appears to be a distinct break in the curve of temperature against this maximum rate at the M_s temperature. The characteristic $\alpha\beta$ inversion of the martensite can be observed dilatometrically immediately after quenching, but it disappears as the isothermal treatment is prolonged and the martensite transforms.

The mechanism of the austenite–martensite transformation during isothermal treatment is discussed, and no reason is found to believe that it is not due to mechanical stress, just like that resulting from the quenching itself. Finally, suggestions are thrown out as to the origin of this stress, and magnetic results are recorded which reveal changes in the austenite during the induction period.

Contribution to the Knowledge of Ternary Phosphorus Alloys. H. Nowotny and E. Henglein. (Monatshefte für Chemie, vol. 79, No. 5, Reprint). The sections for phosphorus 25 to 33·3 atomic-% in the following ternary systems have been examined by X-rays; Cr–Mn–P, Cr–Fe–P, Cr–Ni–P, Cr–Cu–P, Mn–Fe–P, Mn–Ni–P, Mn–Cr–P, Fe–Ni–P, Fe–Cu–P, and Ni–Cu–P. The results of Vogel and his co-workers regarding the miscibility of Fe_3P–Ni_3P, and of Cr_3P–Fe_3P were confirmed; Fe_3P will take up at least 25 mol-% of Mn_3P.—R. A. R.

Vanadium and Its Alloys—A Review of Previous Work. W. B. Pearson. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., pp. 149–159). The chemical and physical properties of vanadium metal are discussed, particularly in relation to the use of controlled atmospheres and refractory materials for containing the metal at high temperatures. Vanadium has a body-centred cubic structure, and the determinations of the lattice constant are briefly reviewed. Four methods of preparing the metal are described: (i) The alumino-thermic method; (ii) the calcium reduction of the pentoxide; (iii) the thermal decomposition of the di-iodide; and (iv) the hydrogen reduction of the chlorides. Malleable vanadium can be obtained by the last three methods. An account of vanadium alloy systems is given under three main headings: (i) Alloys of vanadium with oxygen, nitrogen, carbon, and hydrogen; (ii) the ferrovanadium alloys; and (iii) alloys of vanadium with various other elements. Attention is drawn to some of the experimental methods that will be required for the establishment of equilibrium diagrams of pure alloys of vanadium.

CORROSION

The Electrochemical Behaviour and the Rate of Formation of Oxide Coatings on Metal Surfaces, Particularly Iron. F. Tödt. (Metalloberfläche, 1949, vol. 3, Sept., pp. A170–A173). The author discusses and presents data on: (1) The electrochemical determination of the thickness of oxide coatings; (2) the chemical determination of the thickness of oxide coatings; (3) the rate of formation of iron oxide on iron; and (4) measuring the local-cell activity between the oxide coating and the uncoated metallic iron. With regard to (3), Tamman and his co-workers found that the oxide coating on heated iron increased exponentially with time, but the formation of iodide and chloride coatings on metals followed a parabolic law.—R. A. R.

Effect of Various Aqueous Solutions upon the Reactions at Pure Iron Anodes and Cathodes. W. W. Kittelberger and A. C. Elm. (Corrosion, 1949, vol. 5, Apr., pp. 101–112; May, pp. 155–167). The variations in current flow and electrical potential of a pure iron electrode influenced by changes in an impressed e.m.f., and in the oxygen, hydrogen ion, and chromate concentrations in the electrolyte were investigated. Anodic current-potential curves indicate that in the presence

of chromate ions, dissolved oxygen assisted in the formation of protective anodic films. Films formed under similar conditions were more stable when oxygen was present than when it was absent. It was found possible to force an iron anode into a state of anodic polarization in relatively corrosive solutions if the anodic current density were increased to a sufficiently high value. This value is a measure of the corrosive power of the solution.—R. A. R.

An Accurate Tube Electrometer. S. A. Ginzburg. (Zavodskaya Laboratoriya, 1949, vol. 15. Nov., pp. 1384–1386). [In Russian]. A description is given of an electronic electrometer for the accurate measurement of potential in circuits of high resistance, *e.g.*, in the study of corrosion potential at grain boundaries.—S. K.

Corrosion-Inhibited Fuels. J. M. Michel and K. F. Hager. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2616–2622). Research on the use of inhibitors in liquid fuels to prevent the corrosion of magnesium, aluminium, and steel fuel containers is reported. A very effective inhibitor, Mepasin–sulfamido–sodium acetate, a fraction of hydrocarbons obtained by the Fischer-Tropsch process, has been developed, and some results obtained with it are given.

R. A. R.

Attack of Hydrogen–Nitrogen Mixtures on Steels at 13,000 to 15,000 Pounds per Square Inch Pressure and 204° to 593° C. H. K. Ihrig. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2516–2521). Samples of plain carbon and alloy steel in bar and tubular form were inserted in the catalyst bed of an ammonia synthesis plant and exposed to the above temperature and pressure for 1788 hr. Sections were subsequently microphotographed and analyses were made. The more carbon the steels originally contained the more they were attacked and the more nitrogen they absorbed. Voids were left in the steel throughout their cross-sections. Nickel in amounts of 1·75 to 3·47% added to low-carbon steel does not increase the resistance to this attack. Molybdenum (0·23%) added to 1·75% nickel steel seemed to increase the attack. The damage to chromium steels decreased with increasing chromium. The addition of carbide-forming elements to a 5% chromium steel did not prevent attack. The austenitic chromium–nickel steels were the least attacked, and although they contained the carbide-forming elements molybdenum, titanium, and columbium, they had a thin high-nitrogen case on exposure. All steels showed changes in core structure. The austenitic stainless steels are the best for this service, but samples should be removed and examined after periods of operation.—R. A. R.

Adsorption Balance for Investigating the Gaseous Corrosion of Metals and Alloys at High Temperatures. I. A. Makolin. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1209–1212). [In Russian]. In the apparatus described, the changes in the weight of a specimen of the metal or alloy when exposed to the action of gases at a high temperature are followed by observing through a cathetometer the changes in the length of a molybdenum spring from which the specimen is suspended by a glass thread. Although the spring is kept at room temperature in a compartment separate from the heated tube and is protected from convection currents, the disturbances are such that the flow of gas has to be stopped when observations are being made. The sensitivity is 0·0001 g. with a load of 4 g.—S. K.

Heating Metal Specimens in Corrosion Tests. R. F. Thirsk, G. H. Botham, and G. A. Dummett. (Nature, 1949, vol. 164, Dec. 10, p. 1015). Experiments on the resistance of metals to boiling organic liquids have shown that much higher rates of solution exist when the metal is heated by induction than when the glass apparatus is heated externally by gas. This suggests a useful tool for examining corrosion probabilities where heat transfer through metal surfaces to corrosive liquids is involved.—J. P. S.

Scatter and Multiple Tests in the Measurement of Corrosion. L. Cavallaro and A. Indelli. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 758–761). The authors discuss the causes of the scatter in the results of multiple corrosion tests and other similar experiments and the difficulty of determining the mean value when the scatter is large. They think that the principal cause of scatter lies in the inevitable variations in the metal under test (chemical composition, structure, surface condition, etc.), and that lack of precision in the methods of measurement is of less importance.—A. E. C.

The Effect of Oxygen on Inhibition of Corrosion by Nitrite. M. Cohen, R. Pyke, and P. Marier. (Journal of the Electrochemical Society, 1949, vol. 96, Oct., pp. 254–261). Experiments on the effects of the concentration of dissolved oxygen, and of temperature, on the rate of breakdown of sodium nitrite used to inhibit the corrosion of steel are reported. At any given temperature, an increase in the oxygen concentration decreased the amount of nitrite required for inhibition. At high temperatures and low oxygen concentrations, the rate of nitrite breakdown was low, but the rate of corrosion was appreciable. In some cases considerable time elapsed before the nitrite commenced to break down.—R. A. R.

Engineering Aspects of Cathodic Protection As Applied to Pipe Lines. E. P. Doremus, G. L. Doremus, and M. E. Parker, jun. (Corrosion, 1949, vol. 5, Sept., pp. 273–281). The factors governing the design of an installation for the cathodic protection of buried pipelines are considered. The three recognised criteria for complete protection are based respectively on current density, potential, and the current–potential relationship. Data on current requirements for bare and for coated 8-in. pipelines with different spacings of the drainage points are presented and show that any given pipeline can be protected with the maximum current economy by using a large number of relatively small drainage points. For coated lines, the optimum current drainage from a single point may vary from a few tenths of an ampere to three or four amperes. Costs are discussed and cost analyses of magnesium anode and rectifier ground-bed installations are made.—R. A. R.

Cathodic Protection and Its Application to the Iraq Pipelines. W. C. R. Whalley. (Journal of the Institute of Petroleum, 1949, vol. 35, Oct., pp. 705–734). The principles of cathodic protection are briefly explained and an account is given of the economic and technical aspects of its application to the Iraq pipelines. The scheme adopted comprises two separate and different systems. On the Kirkuk–Tripoli line there are frequent installations fed by a rectifier unit. The rectifiers are of an oil-immersed selenium type with a rated output of 50 V., 40 amp. These units, situated at intervals of 5 to 10 miles, are supplied from an 11,000-V. overhead line through 5-kVA. transformers. The south leg of the system from K3 to Haifa is protected by a fewer number of isolated units supplying direct current by means of isolated unattended Diesel generator sets which are inspected every third or fourth day.—R. A. R.

The Cathodic Protection of Steel Piling in Sea Water. H. A. Humble. (Corrosion, 1949, vol. 5, Sept., pp. 292–302). Work on the protection of steel in sea water previously reported (*see* Journ. I. and S.I., 1948, vol. 160, Nov., p. 342) has been continued by tests on steel specimens immersed below low-tide level, in the tidal zone, and in the splash zone above high-tide level. Corrosion in the tidal zone is very heavy and increases with the time of exposure to atmosphere. When continuously immersed plates are coupled to plates in the tidal zone, attack on the latter is considerably reduced, but corrosion of the former is increased. Cathodic protection is of no value in the splash zone, and only partially effective in the tidal zone. Below mean low-tide level, corrosion can be virtually eliminated by applying a protective current equivalent to 3 milliamp./sq. ft., after the initial deposition of a calcareous coating. Since initial failure will occur in the splash zone, cathodic protection will not prolong the life of steel piling unless protective coatings are applied from some point above the splash zone to below the high-water line. The nearer to the low-water line such a coating is applied, the better will be the protection.—R. A. R.

Corrosion Testing Facilities at Kure Beach, North Carolina. Ivy M. Parker. (Corrosion, 1949, vol. 5, Sept., pp. 303–307). A general description is given of the International Nickel Company's corrosion testing station at Kure Beach, N.C. A wide variety of submarine, tidal, and atmospheric corrosion tests have been and are being carried out; brief notes on these are included.—R. A. R.

A Method for Activating Stainless Steel Specimens Prior to Corrosion Tests. R. O. Bayer, and E. A. Kachik. (Corrosion, 1949, vol. 5, Sept., pp. 308–310). The apparatus for activating stainless steel specimens, and the subsequent corrosion tests consists of five wide-mouth 1000-c.c. Erlenmeyer flasks, a glass cradle, and a balance. The beakers are arranged in series, the first containing the pickling solution (a good one is a mixture of 12·7%, by weight, nitric, 3·2% hydrofluoric, and 0·5% hydrochloric acids), the next three flasks

contain rinse solutions, and the last the solution for the corrosion test. The specimen is lowered by the glass cradle into the first flask and kept immersed for a controlled period, during which gas is evolved. It is then transferred into the other flasks in succession, each movement being rapidly made to minimize the time in air. When the overall loss in weight is large the weight lost during pickling can be ignored, but when the corrosion is very slight, a separate specimen must be used to determine the loss in weight during the controlled pickling time. Some results for 18/8 steel in boiling 1% sulphuric acid and in boiling formic acid are given. R. A. R.

ANALYSIS

Spectrophotometry (200 to 1000 Millimicrons). K. S. Gibson. (National Bureau of Standards, 1949, Sept. 15, Circular 484). This circular is issued to make available to users of spectrophotometers the experience, techniques, and data that have resulted from the work of the National Bureau of Standards in the application of the spectrophotometer to colour research, development, and testing. Various spectrophotometric instruments and methods for use in the ultraviolet, visible, and near infra-red spectral regions are discussed. Errors and their elimination are dealt with, and some types of spectrophotometric standards are described.

Application of Statistical Methods of Control to Spectrographic Analysis. R. Girschig. (Société Française de Métallurgie, Oct. 19, 1948 : Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 719–726). In general, no matter what care and precautions may be taken, the results of several spectrographic analyses of a given alloy will tend to scatter more or less. The application of statistical analysis to these results is described under the following headings : Definition of an ' aberrant ' value as a function of the scatter proper to the spectrographic analytical method ; checking the stability of a method of determination ; calculation of the limits of confidence in the average and the amplitude of a series comprising a number of determinations from another series consisting of a different number of tests ; use of the control limits to eliminate abnormal values from the series ; demonstration of a difference in chemical composition between two alloys ; application of statistical control to spectrographic analysis ; and precision of spectrographic estimations.—A. E. C.

Investigation of the Effect of Sparking and of the Influence of Third Elements in Spectrum Analysis. L. N. Filimonov. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1178–1193). [In Russian]. This is the second contribution on the influence of the sparking process and of the presence in the specimen electrode of ' third elements ' on the results of spectrum analysis. The experimental work was carried out using electrodes of special steels and alloys containing 0·26–2·15% of manganese prepared by melting in an induction furnace. The influence of nickel, chromium, and silicon on the calibration curve for the determination of manganese was investigated. The presence of about 15 atomic-% of nickel gave values for manganese 20% low, whilst a similar concentration of chromium and a concentration of about 22 atomic-% of silicon gave values for manganese 100–300% and 600–1000% high, respectively. Rotating-disc electrodes were used for the investigation of the effect of chromium and nickel on the change with time of the relative intensities of the manganese and iron lines, and an ordinary electrode was used with the brittle, high-silicon alloys. The influence of these elements was found to be great, and is attributed to reactions in the oxidation zone at the point of sparking. The experiments were extended to study the influence of carbon, microhardness methods being used in the examination of the surface layers. Carbon was found to have a marked effect on the silicon curve in the initial stages, but, as decarburization of the surface layer under the spark proceeded, the influence decreased ; sparking in the reducing atmosphere of burning town gas, on the other hand, caused carburization of the surface layer. The determination of silicon in wrought iron was found to be affected by the heat-treatment which the samples had undergone. Experiments with nitrided and non-nitrided samples showed that nitrogen can behave as a third element in the determination of manganese, chromium, silicon, niobium, and copper.—S. K.

Drop Electrode for Polarographic Analysis with Forced Shaking-off of the Drop. V. A. Tsimmergakl. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., p. 1370). [In Russian]. A design of mercury drop electrode, specially suitable for visual polarography, is described, in which the drops are regularly detached by mechanical impacts.—S. K.

Analysis of Gas Mixtures by the Method of Thermal-Conductivity Measurement. V. G. Fastovskii and A. E. Rovinskii. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1157–1161). [In Russian]. A design of gas analyser is described which is suitable for either intermittent or continuous analyses, with automatic recording, of mixtures of gases the components of which differ in thermal conductivity.—S. K.

Interferometric Method for the Determination of Nitrogen and Argon in Gas Mixtures. I. V. Izvekov. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1383–1384). [In Russian]. The construction, calibration, and use of an interferometer for the analysis of argon–nitrogen mixtures are described.—S. K.

Apparatus for the Determination of Carbon Dioxide in a Chemical Absorbent and in Other Carbonates. N. I. Stognii and F. P. Dorosh. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1253–1254). [In Russian]. An apparatus for the gas-volumetric determination of carbon dioxide in carbonates is described in which errors due to parallax are said to be minimized. Close agreement with the results of gravimetric determinations was obtained in tests using this apparatus. S. K.

A Catalytic Combustion Column for Gas-Analysis Apparatus. V. E. Vasserberg and G. M. Zhabrova. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., p. 1256). [In Russian]. A light portable unit for heating the combustion tubes of gas-analysis apparatus is described. Heat is provided by the catalytic combustion of methanol, and temperatures up to 400° C. can be maintained.—S. K.

Gas Evolution from Weld Metal Deposits. I. L. Stern, J. Kalinsky, and E. A. Fenton. (Welding Journal, 1949, vol. 28, Sept., pp. 405-s–413-s). The importance of the study of the behaviour of hydrogen in the welding of steel is outlined, and methods of measuring its quantity are described. Besides the straightforward collection of the gas over glycerin, the authors have evolved a new composite method. The quantity is first measured in an apparatus based on the principle that in a closed evacuated system at constant temperature any change of pressure is proportional to the volume of gas evolved into it ; the gas itself is then analysed for hydrogen by passing it over heated cupric oxide at 300° C. and absorbing the water vapour produced in anhydrone. J. P. S.

Determination of Sulphur in Blast-Furnace Slags. A. M. Kargin and V. I. Tkachenko. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., p. 1131). [In Russian]. The following method is said to be satisfactory for the determination of sulphur in blast-furnace slags ; the sample (0·5 g.) in a porcelain boat is covered with exactly 1 g. of a standard sample of steel with the smallest possible known sulphur content, and sulphur is then determined by combustion in a stream of oxygen, the sulphur content of the steel being allowed for in the calculation of results.—S. K.

Baryta Method for the Determination of Carbon in Steel and Other Products of the Metallurgical Industry. B. A. Generozov. (Zavodskaya Laboratoriya, 1949, vol. 15, Sept., pp. 1019–1024). [In Russian]. Improved apparatus and technique are described which were developed for the simplification of the volumetric baryta method of carbon determination. Results obtained in tests with standard samples of steels, ferro-alloys, and other ferrous products showed that by this improved method carbon could be determined with an accuracy of up to 0·001–0·002%. A semimicro variation, using a 0·1–0·005-g. sample, was also tested and found to be of almost the same accuracy.—S. K.

A New Colour Reaction for the Bismuth Ion. B. N. Afanasev and A. V. Uralskaya. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., p. 1177). [In Russian]. The following test is said to be capable of detecting one part of bismuth in 10,000 and to be independent of the presence of the ions of bivalent copper, lead, cadmium, and mercury, or of monovalent mercury : one or two drops of methyl orange are added to the slightly acid solution followed by the dropwise addition of 0·1 *N* solution of the chloramine-sodium salt of para-toluolsulphonchloramide. The bismuth-containing solution becomes colourless and then develops a violet-lilac colour.—S. K.

A Field-Type *p*H Meter. D. A. Vyakhirev. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1376–1378). [In Russian]. A compact instrument for the determination of *p*H by the quinhydrone method under industrial conditions is described.—S. K.

On the Applicability of Various Methods of Determining *p*H to the Analysis of Industrial Effluents. A. V. Evlanova. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1371–1372). [In Russian]. The results are given of tests carried out on the determination by four electric and one colorimetric methods of the *p*H of various industrial effluents, including those from plating and carbonization installations.

The Preparation of Silver Chloride Electrodes with a Stable Potential. A. A. Shcherbakov and T. F. Petrovskaya. (Zavodskaya Laboratoriya, 1949, vol. 15, Nov., pp. 1373–1374). [In Russian]. The preparation and characteristics of a silver chloride electrode which is suitable for industrial *p*H determinations are described.—S. K.

INDUSTRIAL USES AND APPLICATIONS

Wire Ropes. G. M. McLean. (British Engineering, 1949, vol. 32, July, pp. 78–84). The sequence of processes in the manufacture of wire ropes is described and illustrated, details of the different 'lays' and the purposes for which they are intended being given.—R. A. R.

Metals in Clock and Instrument Manufacture. R. E. Tricker. (Journal of The Institute of Metals, 1949, vol. 75, pp. 881–898). The paper discusses the non-ferrous and ferrous metals generally used in the clock and instrument industry. The metals are dealt with in groups: Turned parts, die-castings, pressed and blanked parts, spring materials, magnet alloys, and alloys with special applications.

Metals in Instruments. E. H. Bucknall. (Journal of the Birmingham Metallurgical Society, 1949, vol. 29, June, pp. 55–84: Metal Industry, 1949, vol. 74, Mar. 4, pp. 163–165, 173; Mar. 11, pp. 183–185; Mar. 18, pp. 209–210). After a brief discussion of some general problems involved in the application of metals and alloys in instruments, some specific aspects where there have been recent developments are considered, special attention being given to thermal expansion, elastic modulus, and magnetic properties.—R. A. R.

Some Metallurgical Aspects of Automobile Manufacture. F. D. Brookshire. (Australian Institute of Metals: Australasian Engineer, 1949, May 7, pp. 69–73). Data are presented on the metals, alloys, and metallurgical processes commonly used (especially in the U.S.A.) in the manufacture of automobiles.—R. A. R.

HISTORICAL

The Driving Forces in the Development of Steel. E. H. Schulz. (Stahl und Eisen, 1949, vol. 69, Sept. 15, pp. 655–664). This historical paper reviews the production and use of steel in three periods; the wrought steel age from about 3000 B.C. to about A.D. 1855, the period of transition from wrought to mild steel, and the mild-steel period from then onwards, special attention being given to the stimuli which led to sudden advancements.—R. A. R.

The Fabrication of 'Damascened' Swords in the Merovingian and Carolingian Periods. A. France-Lenord. (Pays Gaumais, 1949, vol. 10, No. 1–2–3, Reprint). By the macro- and micro-examination of longitudinal and transverse sections of a 'damascened' sword and comparison of the appearance of the surface with those of other swords of these periods, the author was able to establish that the ornamental pattern was not produced by welding a filigree pattern on to the surface, but was the external trace of the laminated structure of the steel itself. The laminations consist of pure iron and lightly carburized iron, and the mode of manufacture by welding together thin strips of surface-carburized iron to form a sandwich and then folding back and forth to form close loops, re-welding, forging to shape, and finally welding on the (unpatterned) cutting edges is described.—A. E. C.

English Iron Trade with Iceland in the Fifteenth Century. H. R. Schubert. (Journal of The Iron and Steel Institute, 1949, vol. 163, Oct., p. 158). A trade agreement, dated about A.D. 1420, between Icelanders and English merchants is cited. The goods exported (shipped from Scarborough and Bristol) included horseshoes and knives.—R. A. R.

The Pinners and Wire-Drawers of York 1296–1762. H. R. Schubert. (Journal of The Iron and Steel Institute, 1950, vol. 164, Jan., pp. 3–4).

The English Knife in the Early Middle Ages. H. R. Schubert. (Journal of The Iron and Steel Institute, 1950, vol. 164, Feb., p. 160). A comparison of early English knives made in Northumbria with contemporary knives made on the Continent reveals that the back of the English blade is in two straight lines and points downwards towards the end, whereas the back of the continental knife is curved and points upwards at the end.—R. A. R.

MISCELLANEOUS

Researches of the Institut de Recherches de la Sidérurgie Française. G. Delbart. (Société Française de Métallurgie, Oct. 3, 1949: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 775–778). After a short note on the growth of this French organization known as IRSID, the author indicates the various researches on raw materials (primarily iron ores and coke), on manufacturing processes and on the properties of steel carried out by the Institute or under its patronage, and refers to 24 papers in which results of these investigations have been published.—A. E. C.

Some Questions on the Planning of Works Laboratories. A. A. Eliseev and A. N. Chervyakov. (Zavodskaya Laboratoriya, 1949, vol. 15, Oct., pp. 1240–1243). [In Russian]. The functions to be fulfilled by a works laboratory are considered with special reference to the iron and steel industry, and the siting, design, equipment, and organization of such laboratories are discussed.—S. K.

The Applications of Statistical Methods to Metallurgy. G. Darmois. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 713–715). This paper forms an introduction to the application of statistical analysis to metallurgical problems—the subject matter of other papers presented at the same time before the French Society (*see* below).—A. E. C.

Statistics and Safety. M. Prot. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 716–718). The use of statistical analysis in the calculation of safety factors is discussed.—A. E. C.

Statistical Representation, in the Form of Diagrams, of the Results of Mechanical Tests on Light-Alloy Drawn or Rolled Products. M. Renouard. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 727–734). In the course of a year the testing department of a works will accumulate a considerable number of test results, both qualitative and quantitative. How the interpretation of these data is facilitated by the application of statistical methods is explained in this paper.—A. E. C.

The Use of Statistical Analysis in Heavy Industry. A. W. Swan. (Société Française de Métallurgie, Oct. 19, 1948: Revue de Métallurgie, Mémoires, 1949, vol. 46, Nov., pp. 735–754). This paper is largely based on one in English by the same author entitled "The Work and Organization of a Statistical Department in Heavy Industry, with Particular Reference to the Steel Industry" (Journ. I. and S.I., 1948, vol. 160, Sept., pp. 1–20).—A. E. C.

Study of Adherence of Molten Glass to Heated Metals. J. A. Kapnicky, H. V. Fairbanks, and W. A. Koehler. (Journal of the American Ceramic Society, 1949, vol. 32, Oct., pp. 305–308). A test for evaluating the adherence of molten glass to heated metal is described. Beads of molten glass are allowed to drop on the inclined surface of a polished metal sample which is progressively heated in steps of 50° F. When the glass bead shows a noticeable delay before rolling off the surface of the specimen, it is heated up to another 100° F. and allowed to cool; the highest temperature at which the glass will show no adherence to the sample is read to the nearest 25° F. and called the critical temperature. These temperatures were obtained for several cast irons and non-ferrous alloys. The effects on the critical temperature of various heat-treatments, such as cyaniding, carburizing, nitriding, annealing, and quenching, of the surface roughness and of various glass-mould dressings were determined.—R. F. F.

Elliott Oxygen Pilot Plant. I. Roberts, D. Aronson, M. Atcheson, L. C. Claitor, J. L. Cost, and D. B. Crawford. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2661–2669). A description is given of a 10-ton/day pilot oxygen-producing plant together with details of the process and the results achieved. It was erected during 1946 and 1947, and in the last run of eight weeks a steady production rate of about 10 tons of 95% oxygen per day was obtained. It is claimed that CO_2 is eliminated to an unprecedented degree.—R. A. R.

Dust and Fume Standards. L. C. McCabe, A. H. Rose, W. J. Hamming, and F. H. Viets. (Industrial and Engineering Chemistry, 1949, vol. 41, Nov., pp. 2388–2390). Data are presented on the weights of fume and dust discharged to atmosphere from chimneys of the metallurgical plants in the Los Angeles districts, and a curve is shown for the permissible discharge rates in pounds per hour related to the total weight of all materials used in the plant, excluding air, gas, and oil, but including solid fuel.

R. A. R.

BOOK NOTICES

BULLENS, D. K., and the Metallurgical Staff of the Battelle Memorial Institute. "*Steel and its Heat Treatment.*" Fifth Edition. 8vo. Volume III. "*Engineering and Special Purpose Steels.*" Pp. xxxiv + 606. Illustrated. New York, 1949; John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. (Price 45*s.*)

It is a pleasure to welcome Volume III of this work. The quality of the material and the standard of its presentation are well up to that of the two earlier volumes, and there is no doubt that it completes admirably the fifth edition.

The aim of this volume is to correlate all the known facts about the more important alloy or special steels and their heat-treatment with fundamental principles. The effect of heat-treatment on the suitability of particular steels for various uses is analysed, together with the possibilities of utilizing alternative steels. There are three sections in Volume III, Section I dealing with "Engineering Alloy Steels," Section II with "Constructional Alloy Steels for Heat Treating," and Section III with "Special Steels." These headings are perhaps a little unimaginative and do not hint at the wealth of information to be found under them.

The materials considered in Section I are defined as those used for general construction rather than for applications in which some specific property is desired above all others. After citing the limitations of carbon steels, an excellent survey is given of the effects of additions of alloying elements both in major and minor percentages. The economics of these additions are considered in detail, followed by a discussion of low-alloy high-yield-strength steels. The authors prefer to refer to these as "mild-alloy steels."

Section II relates to steels in which hardenability is the major criterion, and the individual behaviour of the alloying elements is relatively unimportant.

The behaviour of the individual elements in relation to rate of transformation and hardenability is first considered, followed by a study of the additive effect of various pairs of alloying elements. More complex deep-hardening alloy steels are then reviewed and the value of the Jominy test in establishing hardenability specifications is discussed. Much valuable data on many American standard wrought steels is included in this first part of Section II.

Section II continues with a comprehensive chaptero n steel castings. This assembles all aspects of the subject in a very able manner. Designers faced with the perplexing alternative, forgings or castings, should find some pointers here.

The question of toughness and serviceability of steels at high hardness is dealt with in the next chapter and special attention is given to the treatment of rails. The bad effects of quenching stresses are emphasized and an indication is given of how these stresses can sometimes be used to good effect. A separate chapter is devoted to hardened and tempered springs and also to alloy steels for carburizing.

Section III deals with special steels in which, although hardenability is often desired, the main requirement is greater resistance to some severe service than is ordinarily afforded by the steels detailed in Section II. The materials considered include nitriding steels, steels for low temperature service, ferritic and austenitic steels for high temperature use, steels for wear resistance, tool and die steels, high-speed tool steels, and steels for magnetic uses. In each case an excellent critical review of the present state of knowledge is given.

The bibliography in this volume is well up to the standard of the two earlier volumes of this edition. In addition to the normal subject index, a useful index of steels is given referring to all the pages on which each individual steel is discussed. At the beginning of the volume, besides showing the standard American steel numbering systems, a table is given of those British and American specifications which are considered equivalent. Surprisingly few British steels have direct American equivalents.

E. INESON.

CALVO RODÉS, R. "*Metales y Aleaciones.*" Tomo I, Constitucion y Estructura. 4to. pp. xxxi + 626. Madrid, 1948: I.N.T.A.

This is the first volume of a work intended to be a comprehensive treatise on metals and alloys from their nuclear structure to their mechanical properties and treatment. The author is Professor of Metals Technology in the Spanish Higher Aeronautical College, as well as Head of the Application Section of the Spanish Iron and Steel Institute: Sr. Agustin Plana Sancho, Director of the Spanish Iron and Steel Institute has written a commendatory preface, stressing the importance of the scientific study of metals to all engaged in mechanical construction. In this volume, the author first deals briefly with the nature, occurrence, and uses of metals and alloys. He defines metallography in terms used by Dr. Desch, and underlines its basic importance in the study of the relation between the structure of metals and alloys and their physical properties. He then passes on to atomic theory, drawing on Rutherford, Bohr, Planck, and Einstein to lay down modern views of atomic structure and the atomic nucleus. Dealing next with the fine structure of matter, he describes the crystallographic arrangements found in metals, considers the implications of these and classifies the metals accordingly; the assistance given in this by X-ray diffraction is treated at length and its theory and practice carefully explained. From this, the next step is to the microstructure of metals, the growth of crystals from the liquid and in the solid state, and to microscopical analysis, confined, however, to optical microscopy. The structure of alloys is then covered, the substitutional and interstitial methods of the formation of solid solutions, and the theories of the formation of intermetallic compounds being treated at some length; Mott and Jones's views are carefully examined. Thermal analysis and the study of equilibrium diagrams as examples of the possible behaviour of alloys, both binary and ternary, are described; a number of well reproduced micrographs illustrate these examples. The effect of mechanical work and of inclusions on microstructure is then treated with special reference to X-ray examination: with the extension of this to the detection of defects in manufactured articles, and the brief description of other methods of non-destructive testing, magnetic and supersonic, the volume comes to an end. A second volume will deal with the properties and treatment of metals and alloys.—J. P. S.

F.I.A.T. REVIEW OF GERMAN SCIENCE. "*Inorganic Chemistry.*" Part VI. Senior Author, Wilhelm Klemm. 8vo, pp. 356 + pp. 78, indices to Parts I–VI. Berlin, 1948: Office of Military Government for Germany, Field Information Offices, Technical.

This brings to an end the review of inorganic chemistry in Germany, 1936–1946. (*See* Journ. I. and S.I., 1949, vol. 161, p. 279, vol. 162, p. 493 and 1950, vol. 164, p. 126). Special Inorganic Chemistry having been covered and General Researches begun in earlier volumes, this volume concludes the latter subject with three sections on active states and reactions in the solid state, chemical constitution and catalysis, and the chemistry of solutions. An appendix of 40 pages contains a section on new apparatus for physical-chemical measurements, *e.g.*, the density of corrosive gases, a bibliography of recent German books on the subject of the series and a historical section containing references not only to biographical material on the greater German chemists, but to articles on the historical development of individual fields of chemistry. In the section on active states and reactions in the solid state, the various authors deal with such topics as the nature and behaviour of surface active

materials, the reactions of solid materials as one of the fundamentals of powder metallurgy, and the electron-microscope study of finely dispersed solids ; under this heading, too, comes a lengthy study of work on phosphors, not merely on the bases of sulphides and selenides, but also on those of silicates, tungstates, molybdates, etc. The preparation of phosphors for special purposes, such as X-ray screens, or for articles to be visible at a distance, is described. The section on catalysis describes the use of such alloys as copper–nickel, copper–palladium, and copper–platinum as catalysts in organic synthesis ; among non-metallic catalysts investigated are ceria, thoria, alumina, and mixtures of copper and chromium oxides. The section on the chemistry of solutions describes studies of molecular arrangement in aqueous solutions, as well as in non-aqueous solutions such as liquid hydrogen sulphide, liquid ammonia, liquid hydrocyanic acid, and liquid iodine, and the final division deals with solution in molten salts. The standard of presentation, typography, and production remains high.—J. P. S.

LANG, RUTH (Editor). "*Laboratory and Workshop Notes.*" 8vo, pp. xii + 272. Illustrated. London, 1949 : Edward Arnold and Co. (Price 21*s.*)

Although the "Laboratory and Workshop Notes" which appear in the Journal of Scientific Instruments are interesting and instructive, and are of undoubted value to those employed in research work, it is not considered that this book, as compiled from a selection of these Notes, can claim to be of great value as a reference book. It is too sketchy to compete with other modern textbooks on the subject, which are more likely to be consulted when a specific problem arises.

The selection of suitable published notes must always be difficult, but it is a pity that so many of the suggestions included in this book are out-of-date, in that they describe methods of constructing commonly used laboratory tools and apparatus many of which are now available commercially.

It is out of place, for example, to include articles describing the construction of tools for "Cutting holes in the side of a tube" (p. 25) ; "A tool for cutting circular washers or bobbin cheeks" (p. 26) ; "Making small drills" (p. 28) ; "Making **V**-pulleys" (p. 34) ; "Making a stitching tool" (p. 89), etc. The majority of the Notes specially chosen for criticism were written in the early and middle 1930's, at which time they were undoubtedly useful, when research laboratory staff received much lower wages than today and finance for equipping research laboratories with tools and equipment was difficult to obtain.

The value of the book would have been greatly enhanced had the editor confined the selection to those articles dealing with general laboratory practices such as "Soldering and brazing" (p. 84) ; "Laboratory cements and waxes" (p. 61) ; "Drilling small holes in glass" (p. 67) ; "Hints on silvering glass" (p. 123) ; or to the description of generally useful pieces of apparatus not yet available commercially.

In brief, the book provides interesting and instructive, albeit expensive, reading for the research worker and for use in the training of workshop mechanics, but it has little value as a book of reference.

PLUMLEY, S. "*Oxyacetylene Welding and Cutting.*" A Course of Instruction. Revised and rewritten by T. B. Jefferson. Fourth Edition. 4to, pp. ix + 356. Illustrated. New York, 1949 : McGraw-Hill Book Co., Inc. London : McGraw-Hill Publishing Co., Ltd. (Price 29*s.*)

Not many skilled gas-welding operators would be prepared to admit that a novice could become a good welder without personal tuition. If any single book could be considered a challenge to that opinion, it is this one. The authors do not claim, however, that personal tuition is not necessary in learning how to gas-weld and cut ; it is simply a fact that the book is so clear, comprehensive, and 'down-to-earth' that it is difficult to imagine anyone who can read, not making good progress if left entirely to his own resources with the necessary equipment and materials.

It was the intention of the authors of the book to fill a need for a concise course of instruction in the technique of oxy-acetylene welding and cutting, and there is no doubt that the result of this intention has left little room for criticism.

The book begins with a short history of oxy-acetylene welding, which seems to have started in earnest soon after the discovery of a method for producing commercially an economical source of acetylene, that is, from calcium carbide. It then proceeds to show how to set up the welding equipment, to describe the properties of the gases used in welding, and, step by step, how to develop skill in handling both repair and production work.

A great deal of emphasis has been placed on the welding and cutting of small and large diameter pipes. It is generally accepted that the best criterion of a good welder is his ability to apply his art to pipeline welding, particularly where the pipes are welded *in situ* and cannot be rotated, thereby involving in turn overhead, vertical, and downhand welding ; the emphasis on this aspect, therefore, is to be welcomed. Pipeline welding is being used more and more, particularly by heating and ventilating engineers for installations in residences, public buildings, and industrial plants, which involve the use of the smaller pipes. On the other hand, larger pipes are used in many industries, mainly for outside work involving the conveyance of gas, oil, or other liquids over long distances. Of particular interest and value in the pipe-welding chapters are the data on end preparation of pipes where elbows, right-angle bends, and branch connections are to be made. Voluminous data are given for the preparation of templates for this purpose for a wide range of pipe diameters, thereby eliminating the necessity for the difficult and time-consuming process of producing the required shape for each individual job encountered.

Other chapters are devoted to brazing, welding of lead, light metals, brass and bronze, boiler and firebox welding, and hard-surfacing and reclamation. The more recent techniques are described in the welding of alloy steel, magnesium alloys, and silver brazing. The closing chapters should interest those operatores who are starting, or who have just started, small repair businesses of their own.

There are so many excellent illustrations and tabulated data that at first glance it appears hardly necessary to read the text. The searching questions which are listed at the end of each chapter, however, make it clear, even to an experienced operator, that it might be worth his while to take the trouble to study the text. He should, however, bear in mind that nothing very new or revolutionary will be found.

No gas welder can consider that he has completed his education until he has studied this book. The only regrettable thought is that the pages of such a magnificent volume will have to be turned over with dirty hands before its full value is realized.—A. J. HIPPERSON.

POURBAIX, M. J. N. "*Thermodynamics of Dilute Aqueous Solutions.*" With Applications to Electrochemistry and Corrosion. Translated by J. N. Agar, with a foreword by U. R. Evans. 8vo, pp. xi + 136. Illustrated. London, 1949 : Edward Arnold and Co. (Price 30*s.*)

The only unsatisfactory feature of this excellent monograph—based on a thesis written by Dr. Pourbaix on his work at the University of Delft—is its title, which is at once too embracing and too exclusive : in fact, it does not represent the contents of the book at all. Admittedly, the subject matter is difficult to define in a short title, for it is the application of certain quite general principles to a series of particular systems ; the best the present reviewer can suggest is "Electrode and Solubility Equilibria in Aqueous Systems : Their Graphical Representation and Application to Corrosion and Other Practical Reactions," which is long and clumsy, but does give some impression of the field covered.

The first few pages of the book deal with the general principles of equilibrium that are used throughout, and pp. 10 to 52 form an admirable introduction to the graphical methods of expressing equilibrium relationships that the author has made plain during the last 15 years. The graphs wherein the domains of stability of metal, metal ions in solution, and metal hydroxides under various conditions of *p*H and redox potential are indicated, form valuable pictorial summaries of a mass of data. They show at a glance, for example, whether a metal is thermodynamically stable, reactive, or prone to passivity under the

various possible conditions. Detailed diagrams for copper, iron, and chromium are worked out ; these are of considerable assistance in the understanding of the corrosion behaviour of these metals. The complex equilibria of the nitrogen acids and ammonia with water are also fully discussed.

The book will be useful to any metallurgist interested in corrosion, electrowinning and electrorefining, and electroplating ; ferrous metallurgists may also find in it yet another small reminder that iron is just one of some seventy-odd metals, and that its behaviour is usually best understood when it is seen as a member of a large family rather than as a pre-eminent outsider.

The translation maintains a nice balance between a literal rendering of the French of the original, and a paraphrase to the severer style in vogue among the better English scientific writers. The binding and printing of the book are excellent ; the reviewer has found but one misprint (on the dust cover) and his colleagues have noticed but two or three more, a remarkable achievement on the part of all concerned with the production of a text containing so many equations and formulæ. The rather high price is doubtless accounted for by the complications of printing.—T. P. HOAR.

VITALESTA, G. "*Forni Martin, Forni Elettrici. Costruzione dei Forni Lavorazione dell'Acciaio.*" 8vo, pp. 51. Milan, 1949 : Unione Tipografica. (Price 600 lire)

This brochure is intended to bring together and present in a form convenient to the steelworks operator the essential aspects of steelmaking in open-hearth and electric furnaces, bearing in mind the conditions prevailing in Italy. The logical sequence of beginning with raw materials, continuing with descriptions of the plant and processes and concluding with the properties of the products, is followed.

The usefulness of the book would have been enhanced by the addition of a list of contents as well as of references to indicate where the reader can find more information on some of the processes which are necessarily briefly described.—R. A. R.

NEW PUBLICATIONS

AMERICAN SOCIETY FOR METALS. "*Cold Working of Metals.*" 8vo, pp. 364. Illustrated. Cleveland, Ohio, 1949 : The Society. (Price $5)

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Specifications and Tests for Electrodeposited Metallic Coatings.*" Sponsored by the American Society for Testing Materials and American Electroplaters' Society. 8vo, pp. 53. Philadelphia, 1949 : American Society for Testing Materials. (Price $1.25)

BAKER, W. AND J. S. KOZACKA. "*Carbide Cutting Tools, How to Make and Use Them.*" 8vo, pp. ix + 416. Illustrated. Chicago, 1949 : American Technical Society ; London : Technical Press, Ltd.

BARREIRO, J. A. "*Tratamientos Térmicos de los Aceros.*" Madrid : Escuela Especial de Ingenieros Industriales de Madrid.

BLUM, W. AND G. B. HOGABOOM. "*Principles of Electroplating and Electroforming (Electrotyping).*" Third Edition, pp. xv + 455. New York : McGraw-Hill Book Co., Inc. (Price $6)

BRITISH STANDARDS INSTITUTION. B.S. 1121 : 1949. "*Methods for the Analysis of Iron and Steel.*" Part 15 : "*Silicon in Plain Carbon Steels, Low-Alloy Steels and Cast Irons. (Absorptiometric Method).*" Pp. 9. (Price 1*s.*). Part 16 : "*Manganese in Iron and Steel.*" Pp. 8. (Price 1*s.*). London : The Institution.

BRITISH STANDARDS INSTITUTION. B.S. 1121A : 1949. "*Laboratory Safety Precautions in Metallurgical Analysis.*" 8vo, pp. 6. London : The Institution. (Price 1*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 1575 : 1949. "*Cast Iron Pipe Flanges and Flanged Fittings. Class 125 for the Petroleum Industry.*" 4to, pp. 21. London : The Institution. (Price 7*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 1576 : 1949. "*Cast Iron Pipe Flanges and Flanged Fittings. Class 250 for the Petroleum Industry.*" 4to, pp. 15. London : The Institution. (Price 7*s.* 6*d.*)

BRITISH STANDARDS INSTITUTION. B.S. 1609 : 1949. "*Press Tool Sets.*" 4to, pp. 45. London : The Institution. (Price 10*s.* 6*d.*)

BRITISH WELDING RESEARCH ASSOCIATION. "*Recommended Practice for the Spot Welding of Low Carbon Mild Steel Sheet.*" 8vo, pp. 11. London : The Association. (Price 1*s.* 6*d.*)

BUTLER, H. E. J. "*Electric Resistance Welding. A Practical Guide to Spot, Seam, Projection, and Butt Welding Methods.*" London : George Newnes, Ltd. (Price 17*s.* 6*d.*)

CHAMBRE SYNDICALE DES PRODUCTEURS D'ACIERS FINS ET SPÉCIAUX. "*Les Aciers Fins et Spéciaux Français.*" 3e Edition, 8vo, pp. 332. Paris, 1949.

DWYER, P. "*Gates and Risers for Castings.*" Third Edition, 8vo, pp. viii + 375. Illustrated. Cleveland, Ohio, and London, 1949 : Penton Publishing Co. (Price 45*s.*)

GENERAL REFRACTORIES CO. "*Refractories Handbook.*" Pp. 272. Philadelphia : The Company. (Price $5)

INSTITUTION OF PRODUCTION ENGINEERS AND INSTITUTE OF COSTS AND WORKS ACCOUNTANTS. "*Interim Report on Measurement of Productivity.*" 8vo, pp. 15. London, 1949 : Macdonald and Evans. (Price 1*s.* 6*d.*)

JÄNECKE, E. "*Kurzgefasstes Handbuch aller Legierungen.*" Zweite Auflage, 8vo, pp. xx + 811. Illustrated. Heidelberg, 1949 : Carl Winter, Universitätsverlag. (Price DM 78.–)

KACZMAREK, E. "*Praktische Stanzerei.*" Dritte Auflage Erster Band : "*Schneiden und Stanzen.*" Pp. viii + 176. Illustrated. Zweiter Band : "*Ziehen, Hohlstanzen, Pressen, automatische Zuführvorrichtungen.*" Pp. vii + 165. Illustrated. Berlin, 1949 : Springer Verlag. (Price Bd. I DM 13.50 ; Bd. II DM 13.50)

KALLANNER, O. "*Chemical Technology of Metals and Alloys.*" Pp. 174. Brno : Ústov Chemische-Technologie Benešová Technika.

KEIL, F. "*Hochofenschlacke.*" (Stahleisen-Bücher Bd. 7). 8vo, pp. 346. Illustrated. Düsseldorf, 1949 : Verlag Stahleisen m.b.H. (Price DM 32.50)

KLINGER, P. UND W. KOCH. "*Beiträge zur metallkundlichen Analyse.*" 8vo pp. 104. Illustrated. Düsseldorf, 1949 : Verlag Stahleisen m.b.H. (Price DM 15.–)

KÖRBER, F., W. OELSEN, H. SCHOTTSKY, AND H. J. WIESTER. "*Das Zustandsschaubild Eisen-Kohlenstoff und die Grundlagen der Wärmebehandlung des Stahles.*" Neu bearb. von H. J. Wiester. Im Auftrage des Werkstoffausschusses des Vereins Deutscher Eisenhüttenleute gemeinverständlich dargestellt. 3 Aufl. (Bericht Nr. 180 des Werkstoffausschusses des VDEh.). 4to, pp. 24. Düsseldorf, 1949 : Verlag Stahleisen m.b.H. (Price DM 3.50)

KORECKÝ, J. "*Hardening of Steel.*" Pp. 175. Illustrated. Prague, 1949 : Práce. (Price 70 Czech crowns)

LINDE AIR PRODUCTS CO. "*Welding and Cutting Manual.*" Pp. 208. New York. (Price $1.80).

MAZZOLENI, F. "*Lezioni di Technologie dei Metalli.*" Parte Prima. "*Metallografia Generale.*" Seconda Edizione. 8vo, pp. 547. Illustrated. Naples, 1949 : Pellerano–Del Gaudio.

SALAUZE, J. "*Traité de Galvanoplastie.*" 2e édition. 8vo, pp. 748. Illustrated. Paris : Dunod. (Price 2950 francs.)

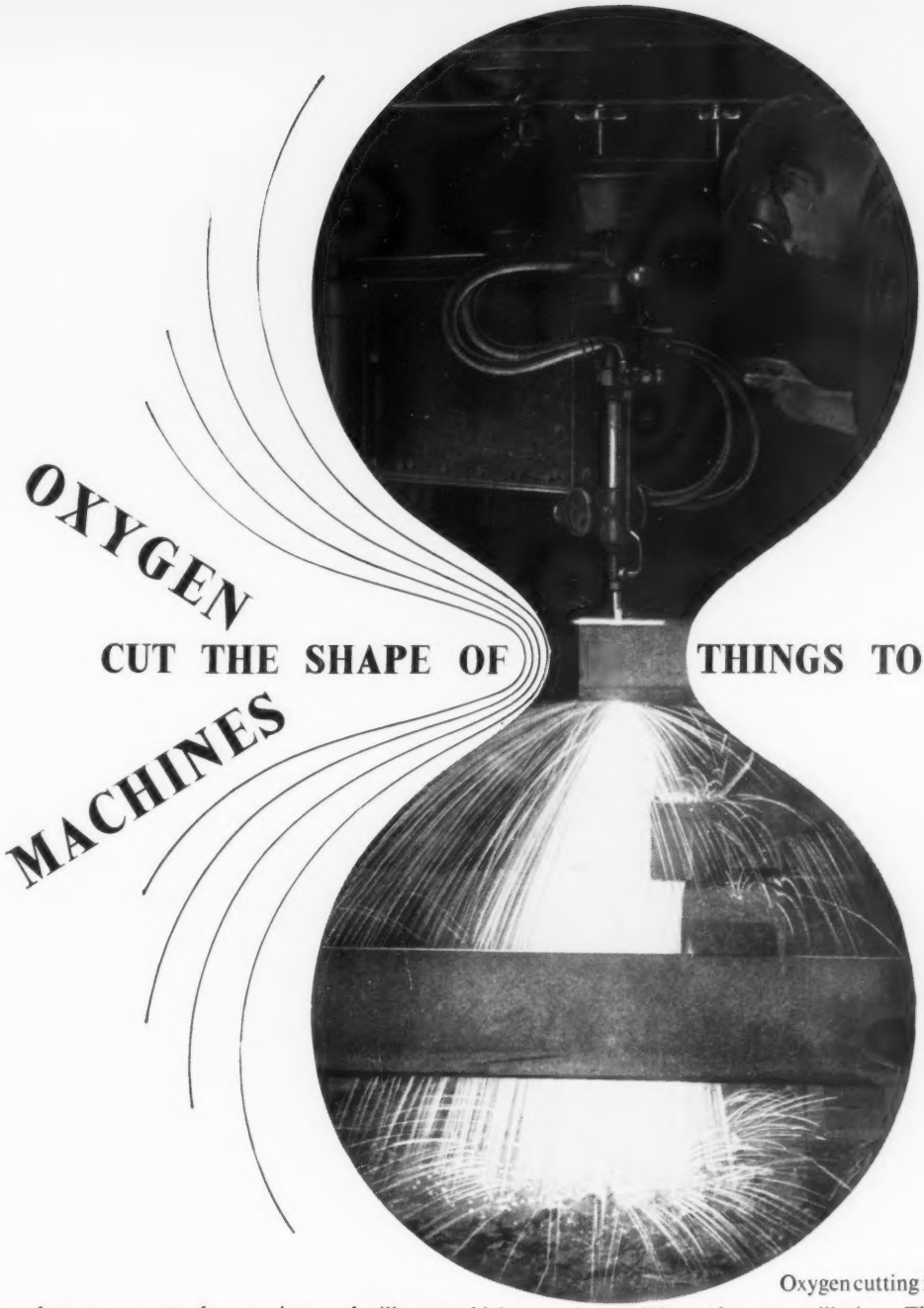
SCIENTIFIC INSTRUMENT MANUFACTURERS' ASSOCIATION. "*A Symposium on Electronics in Research and Industry.*" London : Chapman and Hall, Ltd. (Price 16*s.*)

SOCIÉTÉ DE CHIMIE PHYSIQUE AND THE FARADAY SOCIETY. "*Surface Chemistry.*" Papers presented for a Discussion at a Joint Meeting of the Société de Chimie Physique and the Faraday Society, held at Bordeaux from 5th to 9th Oct., 1947, in honour of Henri Devaux. 4to, pp. vii + 334. London, 1949 : Butterworth's Scientific Publications ; New York : Interscience Publishers Inc. (Price 25*s.*)

WANKE, K. "*Einführung in die Pulvermetallurgie.*" Pp. 198. Illustrated. Graz : Verlag Kienreich. (Price 40 schilling)

WILLIAMS, C. D. AND E. C. HARRIS. "*Structural Design in Metals.*" 8vo, pp. 596. New York, 1949 : Ronald Press Co. (Price $6.50)

WYCKOFF, R. W. G. "*Electron Microscope—Technique and Applications.*" 8vo, pp. vii + 248. New York : Interscience Publishers Inc. (Price $5)



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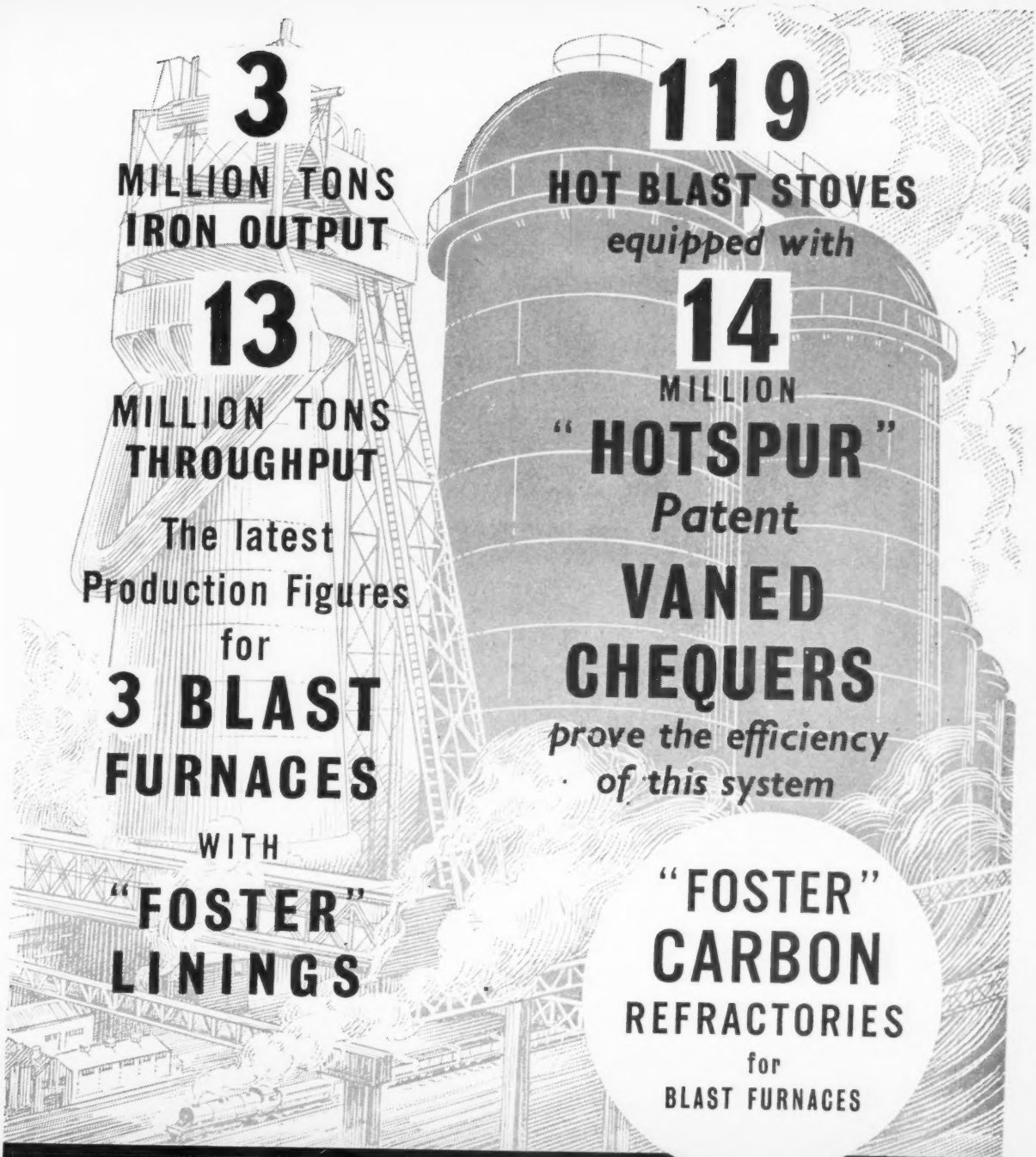

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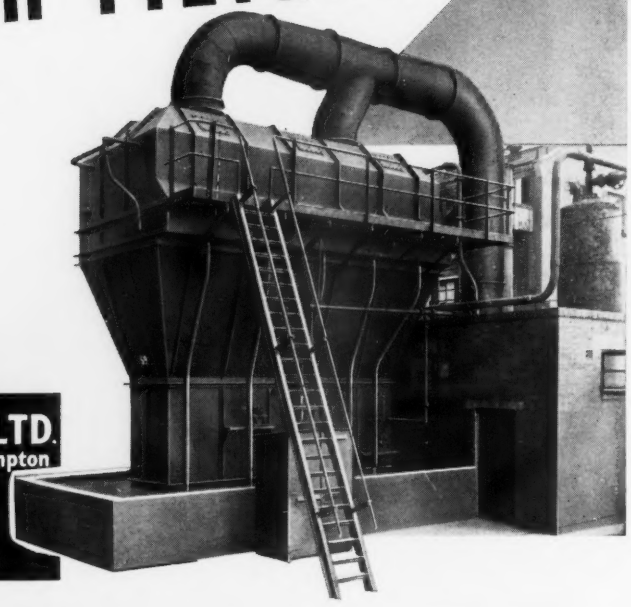

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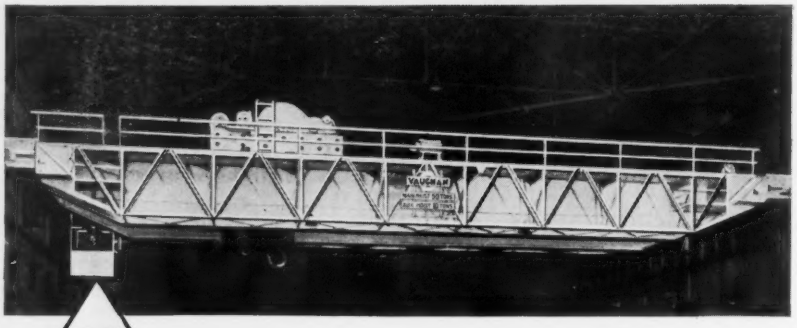

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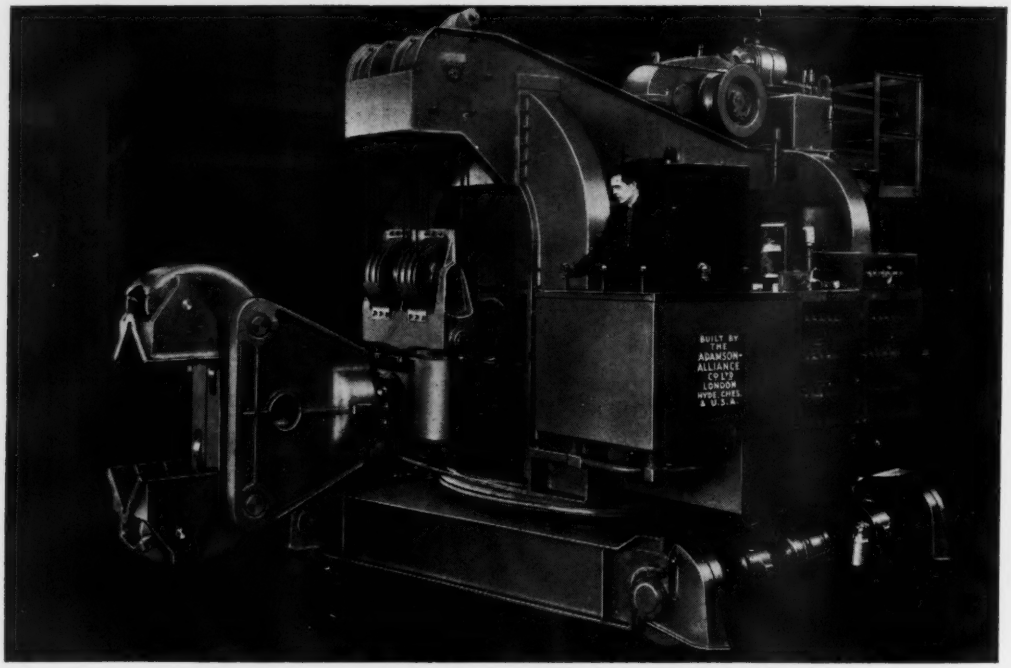

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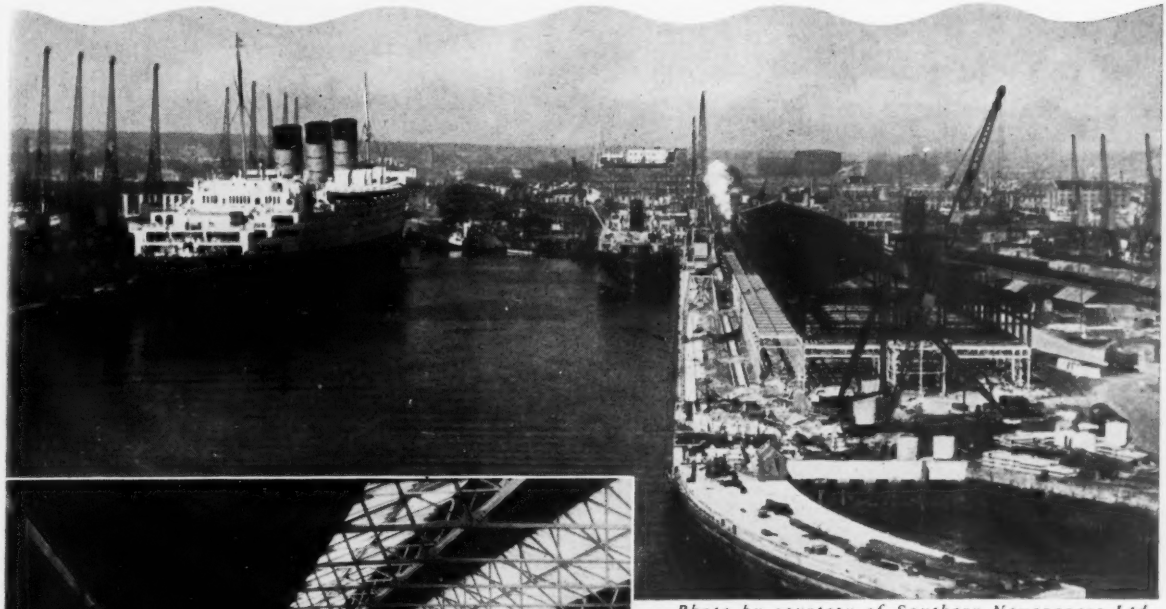

Photo by courtesy of Southern Newspapers Ltd.

This view of the New Ocean Terminal Building now under construction by British Railways, Southern Region, is being protected with British Paints Limited, products, as are also Sheds Nos. 46 and 47 alongside which s/s "QUEEN MARY" is berthed.

Photo by courtesy British Railways Southern Region Docks

New Ocean Terminal Building at Southampton Docks to be protected with B.P.L. materials

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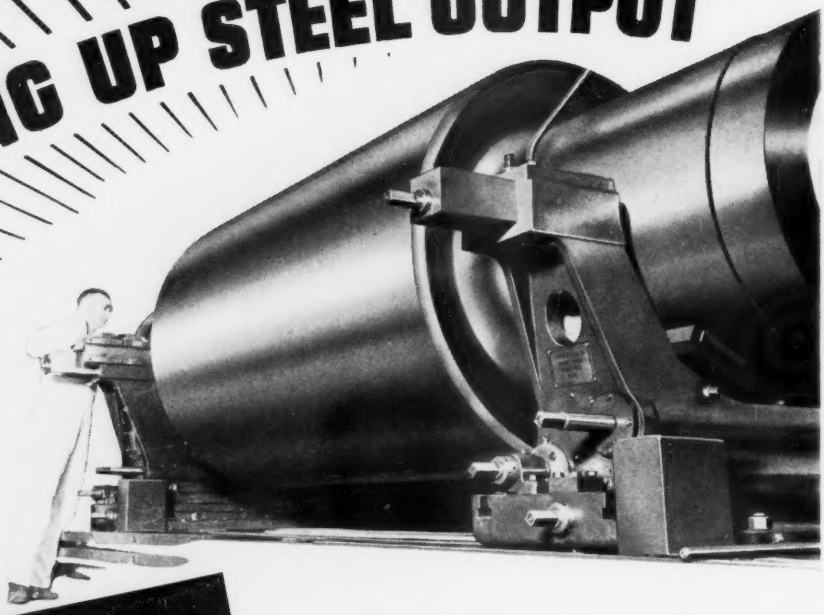

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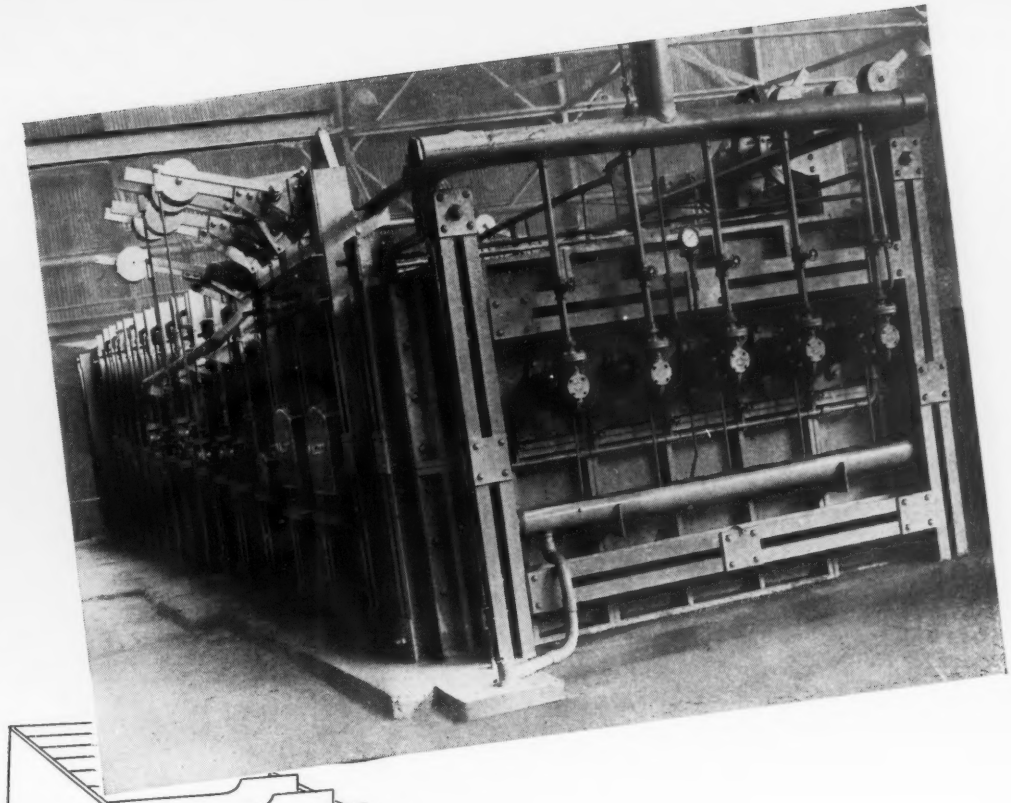

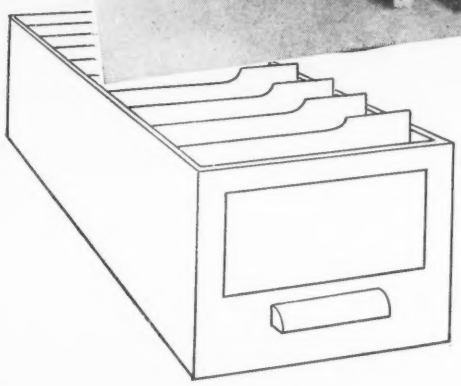

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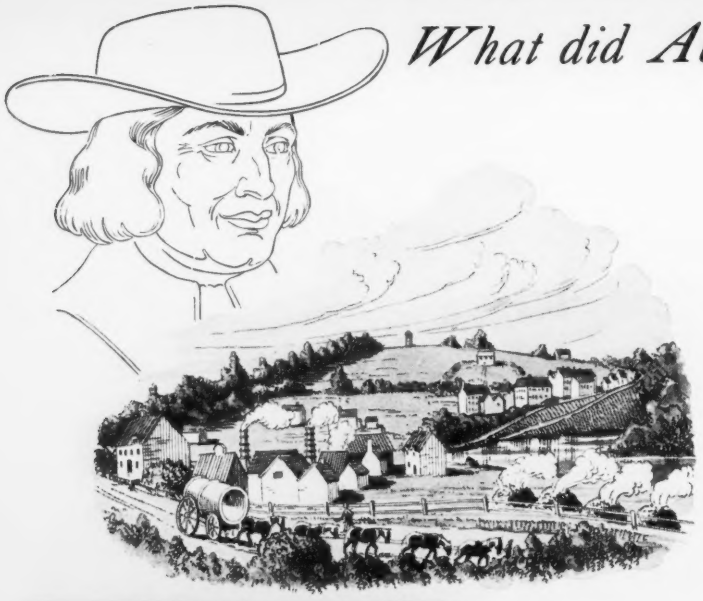

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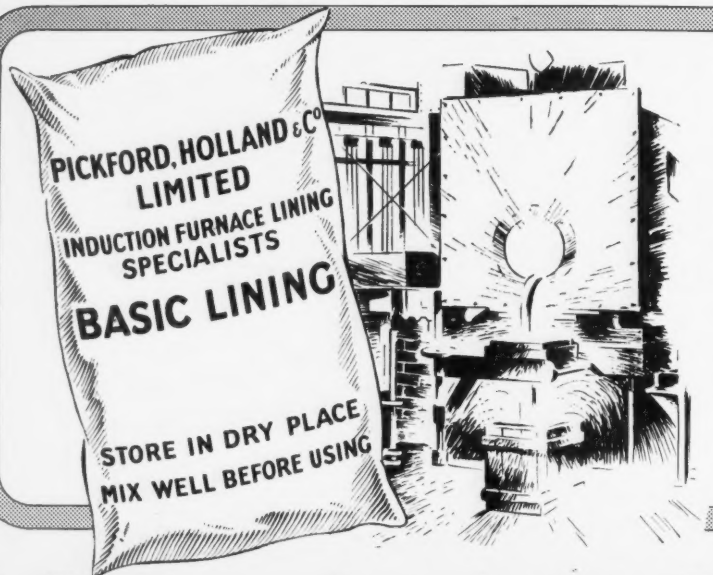

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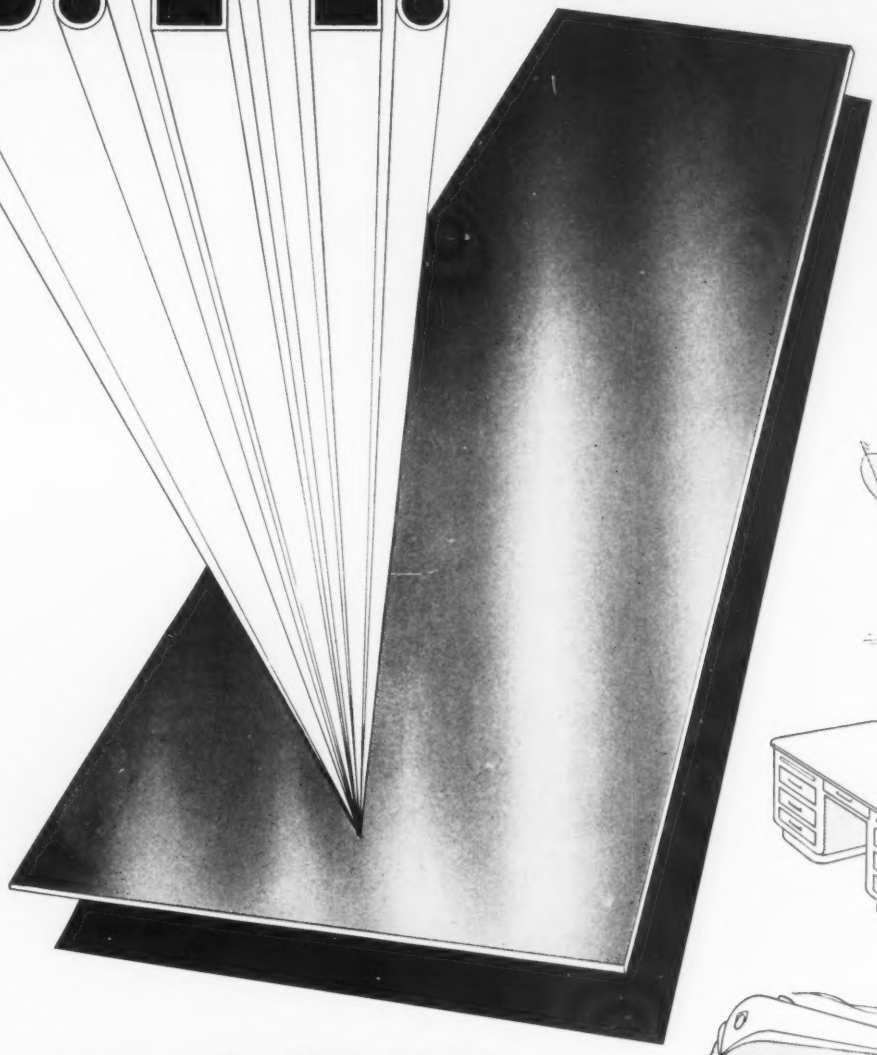

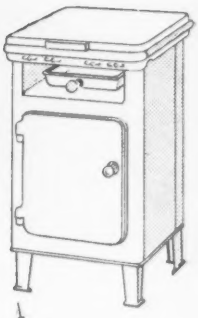

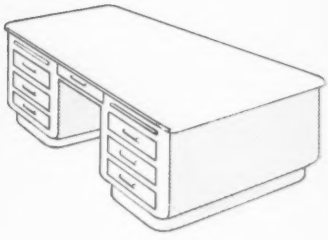

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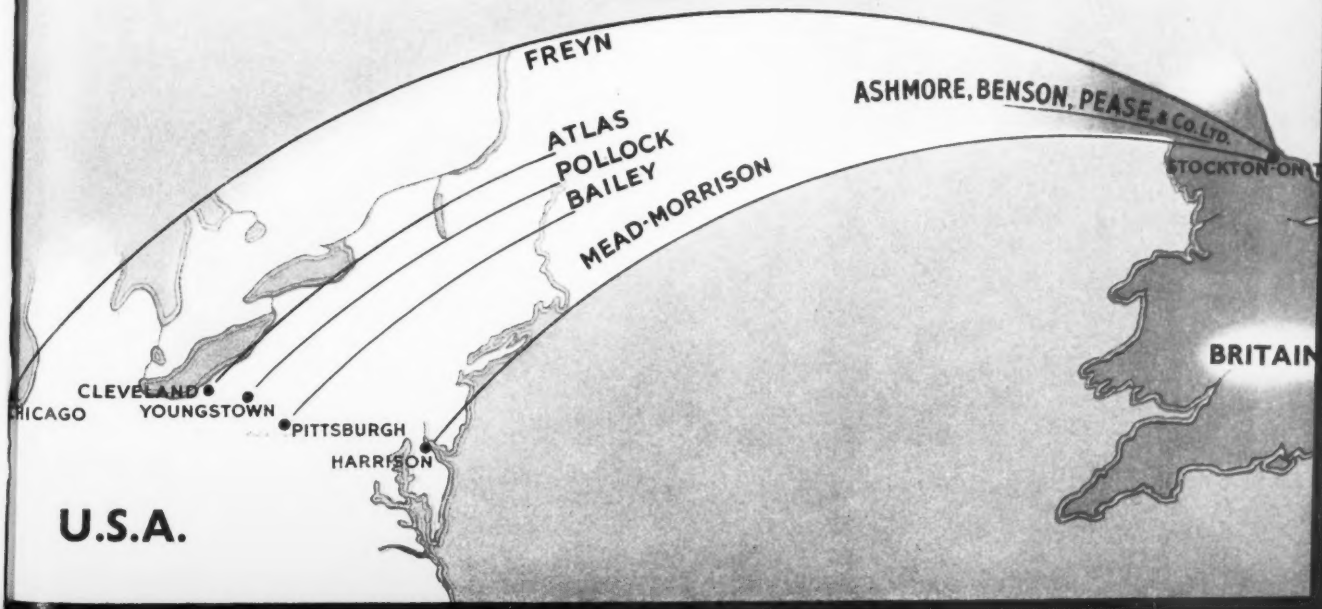

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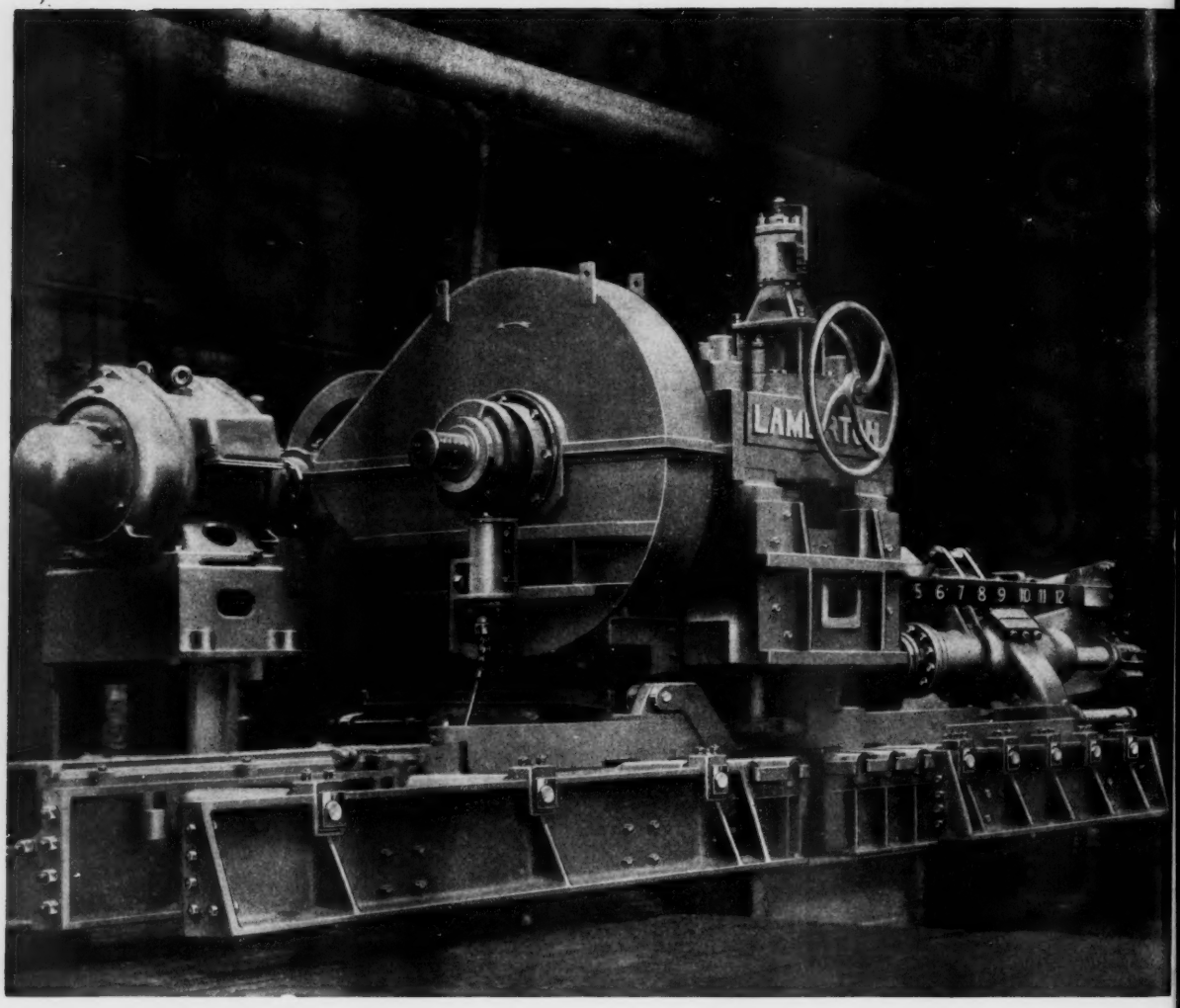

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